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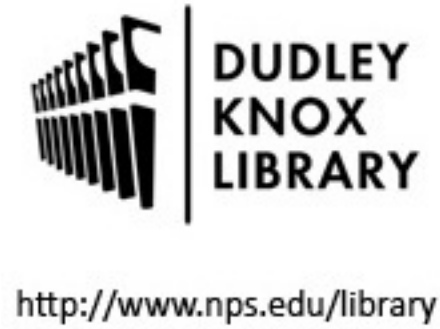

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FINANCIAL MANAGEMENT OF INDUSTRIAL RESEARCH AND DEVELOPMENT

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FINANCIAL MANAGEMENT OF INDUSTRIAL RESEARCH AND DEVELOPMENT

by

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Lieutenant Colonel, U. S. Marine Corps

Bachelor of Science
1959
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A thesis submitted to the faculty of the School of Government, Business and International Affairs of The George Washington University in partial satisfaction of the requirements for the degree of Master of Business Administration.

June 6, 1962

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TABLE OF CONTENTS

		Page
LIST OF FIGURES		iii
Chapter I.	INTRODUCTION	1
II.	RESEARCH AND DEVELOPMENT PROGRAMING	9
	Planning the Overall Research and Development Program Financing the Research Program Selection of Individual Projects	
III.	FINANCIAL CONTROLS	45
	The Budget Accounting and Reporting A Typical Control Operation	
IV.	EVALUATION OF RESEARCH RESULTS	79
	Current Techniques A Truly Comprehensive Evajuation System?	
V.	CONCLUSIONS	99
BIBLIOGRAPHY		104

LIST OF FIGURES

Figure		Page
1.	Trends of Research and Development Expenditures.	4
2.	Research Expenditures as a Percentage of Sales in Selected Companies by Industry Groupings	21
3.	Cost Analysis of a Typical Research Project.	31
4.	Chart of Stability Factors	36
5.	Organizational Expense Budget.	49
6.	Project Expense Budget	51
7.	Typical Coding of Research Costs	61
8.	Expense Statement and Budget Comparison.	65
9.	Expenditures by Project.	66

CHAPTER I

INTRODUCTION

> Many improvements have been made by the ingenuity of the makers of the machines, when to make them become the business of a peculiar trade; and some by that of those who are called philosophers, or men of speculation, whose trade it is not to do anything, but to observe everything, and who, upon that account, are often capable of combining together the powers of the most distant and dissimilar objects.[1]

Obviously, industrial research is nearly as old as industry itself but only in recent years has it been accorded a position as an essential function in industry. The development process was a slow and gradual recognition by businessmen that research efforts were a vital necessity to the continued existence and growth of an industrial organization. It is a generally accepted business axiom that a company must either grow or be lost in the fast pace of modern business affairs. In our dynamic economy the rapid advances of technology are shortening the life cycle of nearly every product on the American market and replacing them with new or vastly improved product versions. The result has been a much greater emphasis on diversification and the development of new products in order to expand present markets.

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[1]Adam Smith, Wealth of Nations, Book I, Chap. i.

Successful companies maintain growth only by a continual process of upgrading present product lines and expanding into new product areas. Only in this way can a company hope to grow with our economy or even remain alive within it. It was this competition within industry which forced management to turn to applied science in an effort to create new products, to improve existing processes, and to utilize what were previously considered as useless waste products in an effort to maintain or increase profit levels. There is no doubt that industrial research is primarily motivated by expectations of profits. The increasing demand for new and improved products occasioned by higher living standards and the potential improvements possible in production processes make these profits available to the firm which can perceive and fill this demand and can take advantage of cost reductions possible through improved production processes.

The requirement for development of these new products and reduction of cost factors in production process has in turn led to tremendously increased expenditures for research and development during the past few decades. Since World War I research and development has become a major facet of industry. It might even be said that research has become a mighty industry in its own right. Many sources indicate that in selected growth corporations as much as 80% of the sales volume results from the sale of products that were unknown as recently as ten years ago. The phenomenal growth of research and development can be seen from Figure 1. This rise in research spending is largely a post war phenomenon, but has roots that go back to the industrial revolution. It is indicative of industry's understanding of the importance of regular,

systematic investment in research and development. This principle and practice of making regular provision for the discovery and development of new ideas and things by industry is likely to provide the spur to growth that came in earlier periods from such developments as steam power, railroads, automobiles, and electricity. Clearly, at some point, research spending must taper off or it would eventually constitute substantially the entire economy, but the limit of the rise in the spending curve is still a long way off. A recent McGraw-Hill study projects the 1969 expenditure at $22 billion. Some observers put the future level even higher; Arthur D. Little Inc. has projected an increase to $35 billion by 1970.[2]

It is not enough for industry merely to discover new knowledge. Industrial research is not primarily concerned with the satisfaction of scientific curiosity in contrast with the primary objectives of research carried on in educational institutions, foundations, and certain governmental agencies. Even though considerable sums are spent on basic research by industry,[3] the real justification for research expenditures must be such that the stockholders, the scientists who do the work, and in the long run, the general public as customers are satisfied that research expenditures are made in their best interests. This is accomplished by the ability of management to

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[2]Leonard S. Silk, The Research Revolution (New York: McGraw-Hill Book Co., Inc., 1960), p. 161.

[3]Various references indicate that approximately 10% of all research expenditures in industry have been allotted to basic research. This percentage varies widely by type of industry from year to year by as much as 17% for the petroleum industry to less than 1% for the aircraft industry in 1958.

FIGURE 1

TRENDS OF RESEARCH AND DEVELOPMENT IN AMERICAN INDUSTRY

Year	Research Performed (millions)	R&D as percent of Gross National Product
1920[a]	40	0.05
1927	100	0.13
1931	170	0.28
1940	280	0.33
1945	990	0.46
1950	1,980	0.70
1952	2,530	0.73
1954	3,950	1.12
1956	6,230	1.44
1958	8,243	1.85
1959[b]	9,553	--
1960	10,497	--
1962	15,000	2.67

[a]Data for 1920-58 from The Journal of Business, Trends in Industrial Research and Development, July, 1960, p. 204.

[b]Data for 1959-62 from the Annual Report of the Joint Economic Committee, Congress of the United States (U. S. Government Printing Office, Washington, D. C., 1962), March 6, 1962, p. 74.

turn research ideas into salable products in order to maintain growth and profits.

A profitable return on the investment involved in research projects is dependent on more than basic research itself. After research must come the engineering required for the design of a product which can be produced economically and which will perform satisfactorily. In general terms, the objective of industrial research is to develop new products, improved products, and lower-cost products. In this connection, the word "product" is used to include processes as well. More specifically, nearly all companies engage in research and development to accomplish the following objectives:

1. To cure existing troubles connected with materials, products, processes, and services, and to prevent such troubles from occurring.
2. To reduce costs involved in the use of materials, products, processes, and services.
3. To improve product or service quality.
4. To reduce consumer's operating or maintenance costs.
5. To develop new uses for existing materials, products, or processes.
6. To develop suitable substitutes.
7. To develop new materials, products, processes, and services.
8. To improve manufacturing techniques or processes.
9. To make use of by-products.
10. To amass technical information.[4]

Obviously, to satisfactorily attain these objectives and meet competition as well as to increase growth rate, industry cannot afford the luxury of mismanaged or uncontrolled expenditures for research and development.

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[4]Darrell H. Voorhies, The Co-ordination of Motive, Men and Money in Industrial Research (Standard Oil Company of California, 1946), p. 41.

Thus, it was inevitable that procedures should be devised to provide the most efficient possible use of research efforts in order to ensure profitability of research expenditures. Companies engaged in research and development must arrive at sound policies which will provide an adequate solution for the following problems which are treated in detail in subsequent chapters.

1. Devising a suitable principle or formula for the overall provision of research funds, both current and long-range, as well as establishing procedures for the selection of the most promising projects.

2. Instituting budgetary and cost control procedures which will ensure that allocated funds are properly spent and that funds which might otherwise be expended needlessly are diverted either to more productive efforts or are saved.

3. Providing a system to realistically evaluate the results of a research and development program.

Types of Research

There appears to be fair agreement among writers with respect to what types of activity are considered research. It was only in the breakdown of research activity into its various facets that some slight disagreement in terminology was noted in the references consulted for this thesis. However, most writers are in general agreement that the three major activities which constitute research are basic research, applied research, and development.

Basic research is a search for new "facts or new physical and chemical laws without regard to their ultimate use, practical application, or

immediate profit."[5] The motivation of basic research is scientific curiosity rather than commercial application.

Applied research is a "search for new knowledge directly applicable to a specific problem and the application of all existing knowledge to the practical solution of the problem."[6]

Development is usually used to denote those engineering techniques by which research results are converted into salable products. It was noted that some authors use development and applied research in almost the same meaning. However, in view of the more generally accepted definition of applied research noted above this use is not considered valid. Although development is considered to be part of research, the character of development is sufficiently different from that of basic and applied research functions that in describing the overall research function the term "research and development" is normally used.

Research and development is "basic and applied research in the sciences (including medicine) and in engineering, and design and development of prototypes and processes. This definition applies to work in the natural sciences and excludes that in the social sciences and psychology."[7] For all

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[5]Darrell H. Voorhies, The Co-ordination of Motive, Men, and Money in Industrial Research, p. 6.

[6]James Brian Quinn, Yardsticks for Industrial Research (New York: The Ronald Press Company, 1959), p. 4.

[7]U. S. Congress, Joint Economic Committee, Congress of the United States, Annual Report on the January 1962 Economic Report of the President with Minority and Other Views, 87th Cong., 2d. Sess., 1962, p. 74.

practical purposes the terms industrial research, research,and research and development can and are used synonomously as an all-encompassing term.

Two other terms commonly used in connection with industrial research activities and which merit some discussion are "offensive" research and "defensive" research.

Offensive research is generally used to denote that type of research which is undertaken by a company in an effort to obtain a competitive advantage over its rivals within an industry through the introduction of new products designed to capture a larger share of the available market.

Defensive research normally designates research which is forced on a company solely to maintain its competitive position within an industry. It is usually aimed at improving the efficiency of operations and the quality and utility of products. The necessity of defensive research is self evident when it is considered that to remain in business in our economy a company must sustain operations and product quality in a competitive industry.

CHAPTER II

RESEARCH AND DEVELOPMENT PROGRAMING

Planning the Overall Research and Development Program

Company goals, as well as demand and cost factors within a particular segment of industry, play a major role in the determination of the size, scope, and timing of individual company research and development programs. Since company goals are largely profit goals, it follows then, as was previously noted, that research is strongly motivated by perceived profit opportunities. This is the real determinant of "how much" and "when," within individual corporate financial capabilities, for research and development.

Setting overall company goals, a function only top management can perform, is the vital first step in research planning. A research program should be devised in such a manner that it effectively and efficiently aids in attaining a company's particular objectives. An aggressive research program, no matter how well formulated, is not sufficient in itself to maintain growth. The program must be an integrated part of the long-range growth plan of the company. Unless this pertinent fact is kept in mind the research program will usually drift towards studies that fascinate individual scientists, toward pet projects of key executives, or toward short-run,

trouble-shooting actions that have little relationship to the company's real objectives. For example:

> Because of the persistent urging of one executive, an oil company started a large program in biochemistry. Although the research people achieved moderate recognition through scientific publications, the company never utilized their findings and it never explained to them how their work would eventually benefit the company. In effect, the company had not related the need for this kind of technology to company goals. Eventually the biochemistry group's morale broke, and its best men left the company. Nevertheless, because of the enthusiastic executive, the company still supports work in this area.[8]

This happened because management failed to relate the research and development program to the objectives of the whole corporation. There is little point in developing products which are outside the scope of the skills and business experience of a company unless it is prepared to expand into these new lines. Nor is there any point in improving a product beyond the quality necessary to please the consumer. Management must exercise caution, however, that the organizational goals are not defined so strictly as to preclude potentially valuable research or so broadly as to be meaningless.

Type of Business

One of the key questions a company must ask when establishing goals is what business does the company want to be in? This can be a major determinant of the direction the research and development program will take. Goals should be set in terms of the "functions" a product performs, rather than in terms of a particular "technique" by which a product performs its

---

[8]James Brian Quinn, "Long-Range Planning of Industrial Research," Harvard Business Review, July-August, 1961, p. 88.

purpose. Researchers can then look at the purpose intended and possibly find a better product to achieve the same purpose. Nelson[9] points out that established firms, even progressive ones, are often backward about introducing radically new products. The established firms of the communications industry--Bell Telephone and General Electric--were not interested in radio. Established aircraft-engine companies would not work on the new jet engine when the concept was first proposed. These companies were thinking in terms of techniques, rather than functions at the time these incidents occurred.[10]

Rate and Direction of Growth

Another consideration which is a major determinant of the type, size, and scope of the program is the rate of growth which is desirable for a company. Financial capacity, management skills, market demand, and other considerations generally limit the rate at which a company can realistically hope to grow without creating stresses which could pose formidable problems to corporate existence. This growth rate in turn affects the total research program and the amount of effort being expended on short-term and long-term projects. A company should grow at a rate feasible to its particular limitations and must develop its research program in consonance with this

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[9]Richard R. Nelson, "The Economics of Invention," The Journal of Business, April, 1959, p. 109.

[10]Obviously, a complete about-face has been done by top management of these companies in the past 30 years. The progressive research of Bell Laboratories, the advanced electronics research being performed by General Electric, and the transition of aircraft companies from manned aircraft production to rockets give adequate evidence of their proper definition of corporate goals. Albeit, there are companies today which persist in defining goals in improper terms.

objective. One measure of gauging this relationship which has been suggested is simplicity itself and appears to be a really practical measure. If the flow of new products, product improvements, and process improvements stays just ahead of a company's capacity to exploit them, then the size and scope of the research effort appears about right. If on the other hand, pressure from sales, advertising, or manufacturing for more product ideas is felt very often, then this is an obvious symptom of too light a research effort.[11] On a long term basis then, maintenance of a proper level of research effort is reasonably assured by an orderly expansion of the research organization at about the same rate as the rest of the business.

Another aspect of overall research program planning is in what direction and by what method is intended growth to take place. Is the company to expand vertically within present product lines or horizontally into new product areas at the same level of manufacture and distribution? This determines whether a company will specialize in limited fields or will expand into broad-line areas. Obviously, these considerations will have a tremendous impact on the size and direction of the company's overall research program. Also, if growth through research is planned, rather than growth through acquisition or merger, then the whole posture of the company will need to be adjusted accordingly and the size and emphasis of the research and development program must be oriented in this direction.

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[11]N. B. Tucker, "Budgeting for Research," The Commercial and Financial Chronicle, July 10, 1958.

It is interesting to note at this point the impact that a properly designed research effort can have on an industry's growth. There is little doubt that the technological changes brought about by applied research have wrought tremendous changes in our economy during recent years. The steady development of new products in the drug industry has helped raise the sales of the five leading drug companies by 210 per cent during the ten years between 1947 and 1957. In addition, the Westinghouse Electric Corporation has stated that 60 per cent of its 1956 sales volume was due to products introduced since World War II.[12] One of the most striking examples of the results that research can have on an industry's growth or maintenance of relative position is the cotton textile industry. Since World War II, the development of synthetic fibers had made serious inroads on the demand for cotton goods. Recognizing this and the possible disastrous consequences to the cotton goods industry, an extensive research program was launched about 1950, with highly successful results. The development of wrinkle-resistant and no-iron cottons recaptured a large portion of the market the industry was rapidly losing to nylon, dacron, and other new materials, themselves the result of extensive research efforts.

There are certainly other considerations, such as financial capabilities which are discussed in Financing the Research Program that should be taken into account in developing an overall research and development program, but the aforementioned appear to be the basic long-range objectives that dictate the emphasis to be given to research. Discounting efficiency of operations, growth

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[12]Elisha Gray, II, The Commercialization of Research Results, Special Report No. 20. (New York: American Management Association, Inc., 1957), p. 10.

and proper product development are the key to sustaining an ever-increasing profit level. This may be observed in the actions of short-sighted companies wherein management has not properly correlated research spending with subsequent sales and profits. In these companies research programs may be forcefully motivated by a strictly "defensive" desire to protect profits from competitors which have engaged in an aggressive research program. The more aggressive research there is, the more defensive research must be undertaken to protect profits. Should a company fall seriously behind, its very existence is threatened by the new and improved products being turned out in its field.

Developing the right product for a particular company at the right time is the critical consideration for nearly all companies. The planning of a research and development program must be put in its proper perspective and must fit the overall objectives of the company. The program must project the impact its particular research and development results will have on the company's total plans and the results must be adequate to ensure that they will meet the competitive challenge within the company's segment of industry. This requires active participation in research and development planning by top management, for only top management can formulate the overall company goals towards which the program must be directed. It is apparent then that "the research program of a particular enterprise is not a thing apart, to be developed for technical considerations alone, but an integrated entity dependent upon all those factors which affect the remainder of the company."[13]

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[13]David Bendel Hertz, The Theory and Practice of Industrial Research (McGraw-Hill Book Company, Inc., 1950), p. 133.

Financing the Research Program

Among the basic factors which a company must consider in establishing its overall research program are the size of the company and its financial status. These will clearly have a significant bearing on the size of research program to be established. The two most important considerations in this respect are the amount of working capital which can be made available for research operations and the amount of investment capital which can be made available to utilize the results of research work. These aspects must be considered in formulating the size and scope of the program. Large corporations generating millions of dollars in earnings and depreciation probably do not have a real limit to research expenditures as such, since they have adequate resources to fully exploit research opportunities. However, the average business organization is not in this financial position and must relate research efforts to the availability of capital. Supporting a research program is a drain on company funds available for other company operations or alternate investments and if research costs are excessive could seriously compromise a company's financial position. Consequently, some limit must be established for potential research and development expenditures.

Investment Capital Requirements

The amount of investment capital required for expansion or modification of plant facilities in order to exploit research results is a real cost consideration in developing the total research and development program. Real as they may be, however, it is almost impossible to correlate plant

investment figures with research effort. Though companies having high research expenditures seem to have correspondingly high growth factors, figures are not available permitting analysis of the proportion of growth of plant facilities which is directly attributable to the research effort. Admittedly, estimation of these costs are generally a straightforward engineering problem, taking into account land, construction, and plant operating costs required to put a product on the market once it has been developed in the laboratory. Because of this, they are not normally considered as part of the research and development effort, but management must consider the availability of investment funds in establishing the company's research and development program or exploitation of successful research efforts may be stymied due to lack of investment funds.

It must be recognized that the returns on research expenditures will be deferred and may well require the further investment of capital funds prior to their realization. The establishment of the amount to be spent on research should be in line with projections of investment funds which can be made available when successful projects result in the demand for new or expanded production facilities. In this respect, Charles Allen Thomas, president of the Monsanto Company, points out that well administered research programs produce an accelerated growth rate and will continue to do so as long as we operate in a free market.[14] Management must be prepared to face unexpected requirements for investment funds brought about by technological breakthroughs in new product development.

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[14]Phillip R. Marvin, Top-Management and Research (Dayton, Ohio: Research Press, Inc., 1953), p. 46.

Cost of Research Operations

Assuming that the general outlines and direction of the research program have been established, the next problem is to decide exactly how much the total research budget should be. Care must be exercised in this matter so that the research budget is not fixed in advance of the establishment of the research goals. The program must be pointed in the direction indicated by the long-range objectives of the individual enterprise, but it also must be within the financial capability of the company or the program is not in balance with overall company operations. Establishing the total amounts to be expended prior to designing the program can easily lead to fiscal irresponsibility in this area, possibly permitting the undertaking of projects which are not in consonance with company goals or, on the other hand, restricting research effort to the extent that product development falls behind rising demand for the product function involved.[15] However, even though the proper approach is exercised, the expenditures which are potentially available will be limited by the working capital of the company and the requirements of other departments. Therefore, the decision as to the upper limit of the amount which can be safely expended on research for any given period is one which merits serious consideration by top management. This decision must be made with full understanding and grasp of several pertinent facts.

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[15]The term "product" does not aptly describe what is meant here. More apropo is the term "product function," which to this writer describes a service or function that may be beyond the scope of a particular product. For instance, radios, telephones, television, wireless are all products; particular techniques used to perform the product function of communications.

One of the most important considerations in setting the size of the research budget is that the level of financial support be fairly stable from year to year. Research cannot be turned on and off. To preserve any semblance of continuity it must be maintained on a going-concern basis. The successful termination of many projects may be several years away and provisions for research should be made upon this long term basis. Only those sums should be earmarked for research which a firm can afford to maintain over a period of years. Stability in a research organization is probably more important than in any other department in a company. The organization can be readily expanded, but not nearly so readily contracted without harmful results. This means a company must maintain a continuing and experienced nucleus of personnel well acquainted with the research objectives and the technical problems being encountered. Key men and even lesser personnel cannot be quickly engaged and made effective for a peak load period and then released.[16] The ceiling on total spending then should not be lowering and raising from year to year or the possibility of losing extremely valuable project results arises. Even though cuts in research budgets are a relatively painless way to conserve badly needed funds, such cuts can result in serious damage to a company's goals in the long run. Management must realize that research takes time for fruition, and cutting a worthwhile project off in the middle means a complete loss of those funds already expended. Hertz makes this analysis of the relationship of time to research activity:

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[16]Darrell H. Voorhies, The Co-ordination of Motive, Men, and Money in Industrial Research, p. 54.

> The player who withdraws from the game before the hand is played out never wins the pot. We have seen examples of one-year research projects that produced nothing tangible in eleven months and then hit the jackpot in the final weeks. Much depends on the organized plan of attack, which may be such that a final integration of facts cannot come until the last stage. The fact that each of the researchers' monthly reports does not contain a startling new discovery does not mean that progress has stopped.[17]

No one seems to have a real formula or standard for determining just the right amount to spend on the total research and development program. The problem is to arrive at a proper optimum research expenditure for the company concerned--one that is not plush on the one hand, yet adequate to protect the company's future on the other. Useful guiding principles, however, are extremely hard to come by. Various writers have proposed quantitative points of reference for this purpose ranging all the way from total assets to number of employees or miles traveled by the sales force. Several of the more common guides or rules-of-thumb used are: (1) a percentage of sales, (2) a percentage of capital base, (3) increasing expenditures by a percentage factor each year to obtain a similar company growth rate, and (4) matching or exceeding competitors' expenditures.[18] About 25 per cent of the companies responding to a 1948 NAM inquiry stated that they attempted to keep their total research budget a relatively constant percentage of the value of total sales. Twelve per cent of the companies replying regulated the size of the research budget in accordance with the overall profit rate. But a majority

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[17]David Bendel Hertz, The Theory and Practice of Industrial Research (McGraw-Hill Book Company, Inc., 1950), p. 161.

[18]James Brian Quinn,"Long-Range Planning of Industrial Research," Harvard Business Review. July-August, 1961, p. 96.

of the companies stated that a great many factors influenced the size of the budget: sales and profits, general business conditions, competitors' research spending, suggested laboratory products, etc.[19] In many cases the major factor determining the research and development budget was a government contract.

Though there is considerable disagreement on which base to use, it appears from reference sources that the most common method in vogue today, as well as in 1948, is the basing of the research budget on a percentage of sales. It is interesting to note the variation and trends by type of industry in the percentage of sales used to govern research expenditures. Figure 2 presents research expenditures of selected companies by industry groupings for the years 1939, 1951, and 1958. There does not seem to be any pattern to these expenditures for industry as a whole though, as might be expected, the relatively newer industries seem to spend a higher percentage of sales on research programs. It is likely that the proportion spent within industry groupings is dictated more by competitive forces than by any set rule of percentage on a year to year basis.

A more logical approach to establishing the size of the optimum research expenditure for a company is presented by both Marvin[20] and Quinn[21]

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[19]Richard R. Nelson, "The Economics of Invention: A Survey of the Literature," The Journal of Business, April, 1959, p. 122.

[20]Phillip R. Marvin, Top-Management and Research (Dayton, Ohio: Research Press, Inc., 1953), p. 49.

[21]James Brian Quinn, "Long-Range Planning of Industrial Research," Harvard Business Review, July-August, 1961.

FIGURE 2

RESEARCH EXPENDITURES AS A PERCENTAGE OF SALES IN SELECTED COMPANIES BY INDUSTRY GROUPINGS[a]

Industry	1939	1951	1958
Aircraft	4.4	12.7	3.3
Motor Vehicle	1.5	1.2	2.8
Instruments	2.6	5.8	4.8
Electrical Equipment	2.7	6.4	4.1
Chemical	.86	2.5	4.3
Rubber	1.01	.9	9.3
Stone, Clay, Glass	.34	1.3	2.1
Petroleum	.56	.6	1.2
Primary Metal	.25	.4	1.2
Paper	.49	.5	.9
Food	.14	.3	.9
Textiles	.11	--	1.4

[a]Yale Brozen, "Trends in Industrial Research and Development," The Journal of Business, July, 1960, p. 213.

in quite similar thoughts. They contend that the most successful approach is individual project analysis with all other criteria being used only as general checks on judgment. First, it is necessary to determine the amount of research which is necessary to maintain company objectives and second, it is necessary to adjust these requirements and the objectives of the firm to the resources available for financing a sound research program. Such a program might represent 1% or 10% of total sales. The percentage of sales is unimportant so long as the total figure is the result of an analytical process of establishing research expenditures objectively. Such a process involves individual project analysis to build the overall program from the bottom up, by ranking each project as to how well it fulfills company goals. The projects selected as best for the company are then supported in order of priority up to the limits permitted by the ability of the corporation to support the financial expenditures involved.

Whichever approach management uses, however, it can never be said to always provide the right answer to optimum budget size. Properly spent, research and development dollars are an investment in the future of a company. Properly to determine the size of the program, and sometimes be right, requires an enlightened management which has confidence in research and development and has a good gambling instinct.

Selection of Individual Products

As profit objectives of a corporation determine research program objectives, so in turn do program objectives determine the selection of

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Selection of Individual Products

As profit objectives of a corporation determine research program objectives, so in turn do program objectives determine the selection of

individual projects on which research dollars are to be spent. The basic feature which should guide the selection of individual research projects is that they should conform with the overall program objectives and be within the immediate research capability of the company. Since the solution to a research problem is worth some specific sum of money to a company, an understanding of the relevance of various factors in relation to company objectives is necessary for management to arrive at a sound decision as to what amount should be expended on which project. In this respect, the potential number of research ideas for a specific company is unlimited, and if only a small percentage of these ideas were adopted as projects, the level of research expenditures would far exceed the capacity of the organization for financial support. Consequently, individual research projects must be judiciously selected in order to attain maximum return on research funds.

Factors of Selection

The problem of actually fitting projects into company goals is exceedingly complex and requires much intuitive judgment since the evaluation of project proposals has not been refined to the point where uncertainty as to the attainment of the desired results within the projected time, cost, and market conditions can be eliminated. Ideally, management would allocate research money to those projects which would yield the greatest payoff. However, no amount of management planning and evaluating can guarantee certainty of accomplishment in research and development work. In addition, the timing of results as related to fiscal periods is something which defies the most astute planning of financial managers. Nor can management foresee

that some problems can be solved only at prohibitive costs, if at all. Nonetheless, the need for effective guides to project selection is obvious since any worthwhile research organization will have more research ideas than could possibly be handled within the company's research budget and facilities.

Intelligent selection of projects is dependent almost exclusively on factors relating to company objectives and present research capabilities. If the objective is only to retain present business position and expand at a normal rate, the projects selected would be entirely different from those which would be selected if the objective were the creation of new products to enter a completely new market in the expectation of exceedingly high profits. However, most companies do not have such extreme objectives and have need for an integrated and balanced program. For such a program project selection must concern itself with three areas: (1) present products, (2) foreseeable new products, and (3) basic research.[22]

The selection of projects related to present products concerns itself with the need to support present lines two to ten years in the future. This involves assessing what will be required to keep products attractive to customers, competitive substitute items, and changing customer needs. Present technology and products are then compared with what is needed in order to identify gaps. If gaps exist, defensive basic research or applied research can be instigated to fulfill company needs and fill foreseeable gaps in the present product line.

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[22]Quinn, "Long-Range Planning of Industrial Research," p. 97.

In the area of new product development, planning again must identify market needs and work backwards to research and development projects designed to meet those needs. The new market application must be matched against present projects and gaps pinpointed. These gaps can then be filled by applied research or basic research, whichever might be indicated.

If present product and new product research and development will not enable a company to meet its goals, the company may need to develop entirely new knowledge for commercial application. This can be obtained only through basic research. Here the planning process is reversed. The scientific areas which may provide the foundation for commercial products compatible with company goals must first be identified. The element of faith in research and development must be strong in such a project since the probability of a given project leading to a commercially usable result is much lower than in applied research. Many companies have analyzed their results over long periods of time but none have come up with a method of analysis with sufficient reliability to be used in planning basic research expenditures.

Obviously, projects cannot be selected only in the void of technical aspects alone. Many other relevant business considerations must be weighed in making project decisions. With regard to these factors, there are three general groups into which they can be classified.

The first group of factors are those related to the effect of the project on the current operations of the company. This category is extremely important since research projects must be designed as an integral part of company operations. Projects which do not fit into the company's pattern of

operations or which might cause dislocation of present product manufacturing should be implemented only if management is willing and able to cope with the problems inherent in organizing new facilities. Within the scope of these factors is the technical feasibility of the research approach being proposed. Even though the economics of product appear favorable, it must be recognized that the assumption that a certain approach will produce desired results is not always valid. Failure of the proposed approach to produce results may require reappraisal of all other factors which may completely alter the economic picture. Consequently, the financial aspects of several possible approaches should be considered in order to properly evaluate the project proposal.

The second group of factors is concerned with the results of the research investigations. If the research reaches a successful conclusion, the results should be of such a nature that they can be utilized. If not, the purpose of the project cannot be entirely justified in terms of value to the company. New products should normally be of the type that can be handled within the scope of existing marketing channels, production facilities, personnel capabilities, and managerial skills available to the company. Within this group is the important factor of project timing. Should the product be marketed significantly before competitive products appear, the return to the company will probably justify almost any research effort. But, if the results cannot be made available within a reasonable time, implementation of the project proposal may not be justified.

The third group of factors relates to the economic aspect of the research program and the product developed. Obviously, the potential return based on estimated sales volume and production expense must be favorable in order to justify expenditure of funds on research and product development. Actual development costs must not be overlooked since they usually represent a very significant portion of the overall costs of a new product. In addition, the investment in additional production facilities which might be required must be taken into consideration, otherwise a company may be wasting research effort on products which it cannot afford to market. All this financial information is vitally important since it permits the project to be evaluated against known parameters, such as current return on present products the company is enjoying, as well as other project proposals.

As can be seen from the above, the selection of individual projects from among the proposals submitted requires an evaluation of many factors, the majority of which can be evaluated only on a judgment basis. The first group relating the project to company operations is important in defining the product function area in which projects should be conducted and serves to eliminate those projects which are outside a company's research interests. The second group relating research results to possible utilization are used to determine whether expected results fall within existing production and marketing capabilities of a company. If they do not, management must be cognizant of this fact and be prepared to cope with the problems involved. The last group relating to the economic aspects of a proposal are considered as the key factors in project selection. Other factors tend to eliminate

possible projects but the final choice between two or more projects which meet all other requirements rests on the potential return to the company of each project being considered.

Research Project Proposals

It is interesting to note the actual mechanism involved in the selection of a project for incorporation into the research and development program. Most companies initiate the selection procedure by preparing a written research project proposal. In a survey conducted by R. N. Anthony,[23] over 90 per cent of 395 participating companies indicated that project proposals were utilized to some extent for this purpose. Participants of a conference of research administrators held at the University of California at Los Angeles in May, 1952, stated that such project proposals originate from numerous sources.[24] Proposals often come from consumers of the products of the company either by informal suggestion or by formal request, and sometimes from the sales division or the manufacturing division, commonly as a by-product of work that is already going on. Too, new developments in science or new products created by other firms stimulate laboratory workers to suggest a project.

Regardless of point of initiation, the project proposal generally contains the following information: (1) estimates of the personnel and other

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[23] R. N. Anthony, Management Controls in Industrial Research Organizations (Boston: Graduate School of Business Administration, Harvard University, 1952), p. 113.

[24] I. R. Weschler and P. Brown (eds.), Evaluating Research and Development (Los Angeles: Human Relations Study Group, Institute of Industrial Relations, U.C.L.A., 1953), p. 20.

resources required to conduct the proposed research and development, (2) the technical feasibility of the research approach, (3) the results to be anticipated from the research investigations, and (4) the anticipated completion date. Anthony's survey indicated the relative utilization of these factors. Over 75 per cent of the participating companies included project cost estimates, 81 per cent included manpower estimates, and 68 per cent included the estimated completion date. Some companies utilized a project proposal form which contained a long list of information relative to the specific project, but this was not normally the case. Usually, this information is compiled as the proposal is routed to various departments for consideration. The engineering division can provide estimates of plant costs, the marketing division can draw its conclusion as to sales potential, and so on down the line. Eventually, all information which is available and on which a decision may be based should be included. Such information should be digested by all concerned and their opinions as to the proposal should be carefully weighed by those making the decision.

Financial Considerations in Project Selection

There are two distinct aspects to the financial considerations which must be taken into account in selecting individual projects. First is the consideration of the research and development costs and the cost of associated production facilities. Second is the evaluation of the potential return on the investment against the current return on products presently being marketed.

1. Research and Development Costs. The two basic elements of project costs are the labor cost of the individual research scientist with his supporting personnel and the cost of the facilities and equipment required to conduct the research program. To these may be added the overhead costs of the administrative staff and the costs of utilities, etc. Mees and Leermakers state the following distribution of costs: (a) 61 per cent for salaries and wages, (b) 12 per cent for materials, and (c) 27 per cent for overhead.[25] These costs will naturally vary with individual companies, the type of research being performed, and the intensity of research effort. As for the latter, the relationship of intensity of effort to costs is self-evident since salaries and wages represent the largest proportion of costs. Increasing the number of personnel assigned to a project then would significantly increase costs. In this regard, many authors have pointed out that concentration of more and more personnel on a particular research project rapidly reaches the point where addition of more workers becomes uneconomical. Technology can move only so fast; trying to force research beyond this speed is costly and fruitless. Care must be exercised to ensure that no one project is allotted more research workers than the speed of the research progress warrants.

D. B. Hertz analyzes typical project costs as shown in Figure 3.[26] This research project cost a total of $80,000 and required thirty months for

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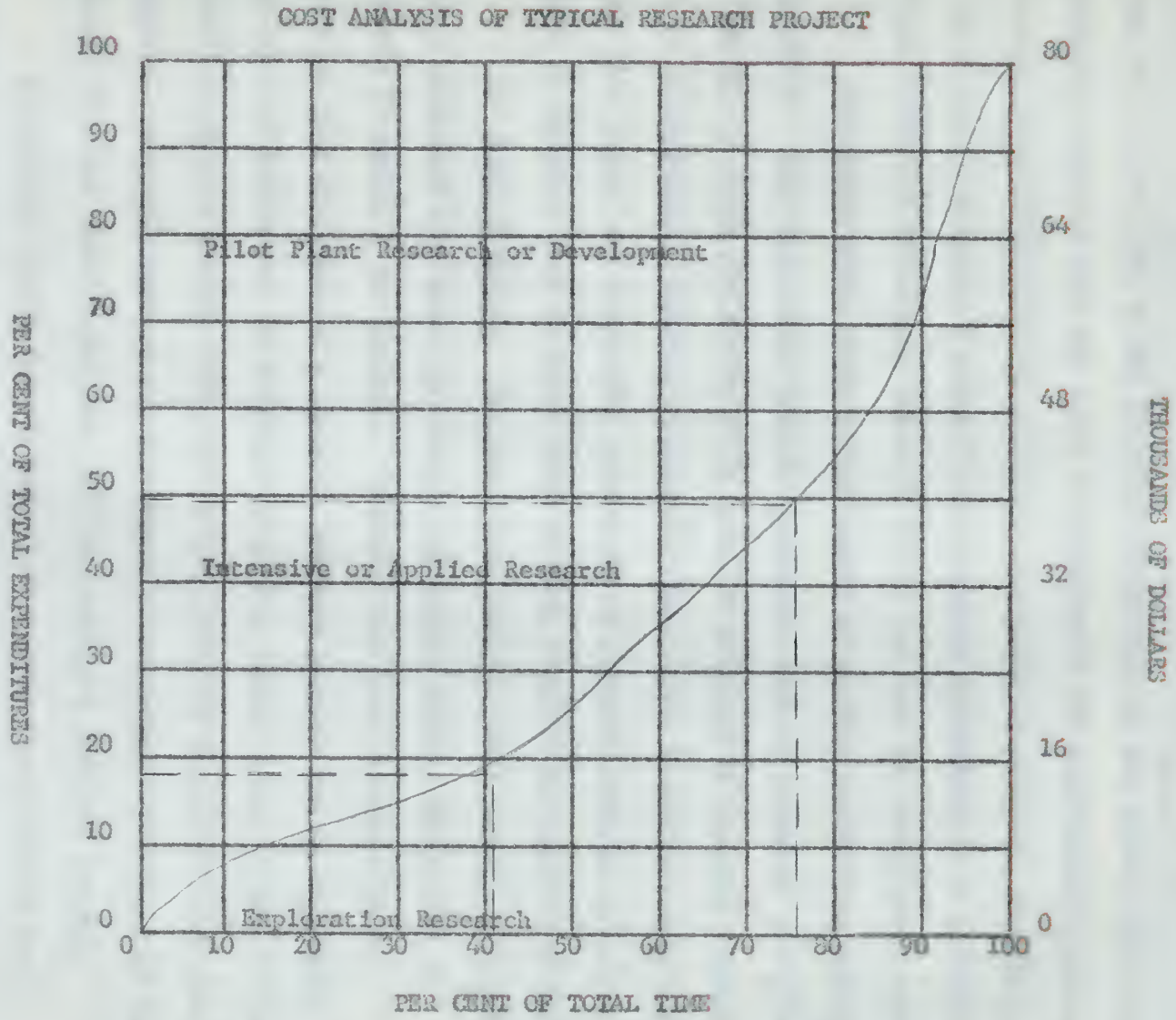
[25] C. K. Mees and J. A. Leermakers, The Organization of Industrial Scientific Research (New York: McGraw Hill Book Co., 1950), p. 299.

[26] D. B. Hertz, The Theory and Practice of Industrial Research (New York: McGraw-Hill Book Co., 1950), p. 156.

FIGURE 3



[a]D. B. Hertz, The Theory and Practice of Industrial Research, (New York: McGraw Hill Book Co., 1950), p. 156.

completion. About 40 per cent of the time and 20 per cent of the funds were expended in the exploratory research state. Applied research utilized about 35 per cent of the time and 30 per cent of the funds while the developmental stage took 25 per cent of the time and 50 per cent of the funds. The obvious implication here is that the costs of development are considerably greater than the costs of exploratory research. For planning purposes, assuming this to be a typical example, a company could program approximately 50 per cent of project costs for laboratory research and 50 per cent for development costs.

Investment costs are a second aspect of project costs which must be considered. This area would include estimated costs of potential new plant, equipment, or other facilities which would be required if research results are to be exploited. Failure to consider these costs in project selection could well negate any successful conclusion of research efforts and could result in complete loss of those funds already expended on research operations.

2. Rate of Return. The above cost analysis will provide a company with a yardstick with which to measure the actual dollars which will be required to market a new product. From this and other information the potential rate of return of a specific research project can be evaluated. This rate of return must be compared to current return being enjoyed by the company on present product lines and to the potential return of other possible projects. This then becomes the key factor in selecting one project at the expense of others which might also fit the company's research program.

One project rating formula used to calculate the potential rate of return of projects is that used by the American Alcolac Company of

Baltimore.[27]

$$\frac{\text{Chances of Technical Success} \times \text{Chances of Commercial Success} \times \text{Annual Volume} \times (\text{Price} - \text{Cost}) \times \text{Life}}{\text{Total Costs}} = \text{Rate of Return Number}$$

This formula does not supply any radically new information but it does crystallize available information in a quantitative form for management's use in project selection. The formula is really a ratio of total net profit expected during the life of a product to the total project cost. A ratio of one (Rate of Return Number) would indicate that only the costs of the project would be recovered; obviously not a very appealing venture.

Since American Alcolac is a small company and is desirous of a fast rate of return, it decided to use the square root of the life of the project in the formula. One of its proposed products, a commercial laundry detergent, looked like a potential gold mine at first glance. Both the market and profit margin seemed good. The research department estimated that its chance of actually producing a detergent for commercial laundries was between 80 and 100 per cent--or an average of 90 per cent. The sales manager estimated that the product's chance of commercial success was 60 per cent. He estimated that the detergent could be made for 13 cents a pound and that the company could sell 3 million pounds a year at 18 cents a pound. The life of the product at this sales level was estimated at 3 years. Research costs were estimated at

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[27]Theodore T. Miller, "Projecting the Profitability of New Products," The Commercialization of Research Results, Special Report No. 20 of the AMA (New York: American Management Association, Inc., 1957), p. 31.

$20,000; market development at $40,000; engineering and pilot-plant work at $40,000--a total cost of $100,000. The formula looked like this:

$$\frac{.8 \times .6 \times 3.0 \times 10^6 \times (18¢ - 13¢) \times \sqrt{3}}{100,000} = 1.2$$

The project Rate of Return Number of 1.2 indicated that the company would do only slightly better than getting its original investment back.

American Alcolac then looked at another surface active agent used as an emulsifier in the rubber and plastics industry. Its chances of technical success were rated at 85 per cent; its commercial success at 75 per cent; its volume at 1,150,000 pounds a year; its sales price at 31 cents a pound; its cost at 19-1/2 cents a pound; and its life at 4 years. The cost of research was rated at $4,000; market development at $1,250; and engineering and pilot plant at $7,500. The calculation looked like this:

$$\frac{.85 \times .75 \times 1.15 \times 10^6 \times (31¢ - 19.5¢) \times \sqrt{4}}{12,750} = 13$$

This project was obviously more attractive than the one with a Rate of Return Number of 1.2

The quantitative profitability analysis method described above is only one of many formulas which can be used for this purpose. Some mode of rate of return analysis is essential but any method is subject to error in estimating market, product costs, etc. In the final return the most vital

asset to proper project selection is keen judgment exercised at every step in the selection of new projects by all the talent available in the organization.

A Typical Project Selection Operation

The evaluation of a proposed project should proceed in accordance with the criteria already presented in this section. Illustrative of the complexity of this operation and the pains to which some companies go in an effort to winnow out the promising ideas from the duds is the below description of the project selection process in the Polymer Chemicals Division of W. R. Grace and Company.[28]

A screening process is used for sorting ideas beginning with a coarse screening, then successive screenings that increase in fineness until the projects that are left are few enough in number and promising enough in caliber to concentrate on in the final fine analysis.

Early screenings are largely qualitative. At Polymer a number of factors are examined and for each factor a rating of "very good," "good," "average," "poor," or "very poor" is assigned. The factors are then arranged into groups and for each group a chart is made on which the ratings of individual factors can be spotted and subsequently connected by a profile line. Figure 4 shows how a new product might appear on a Chart of Stability factors. After a chart has been completed for each group of factors, the entire profile of the new product can be spread out and examined. Too many poor or very poor ratings will show up visibly and vividly, and the new product idea can be discarded. If the profile hovers near the average line, the new product idea is usually put on the shelf for reexamination at a time when brightly promising

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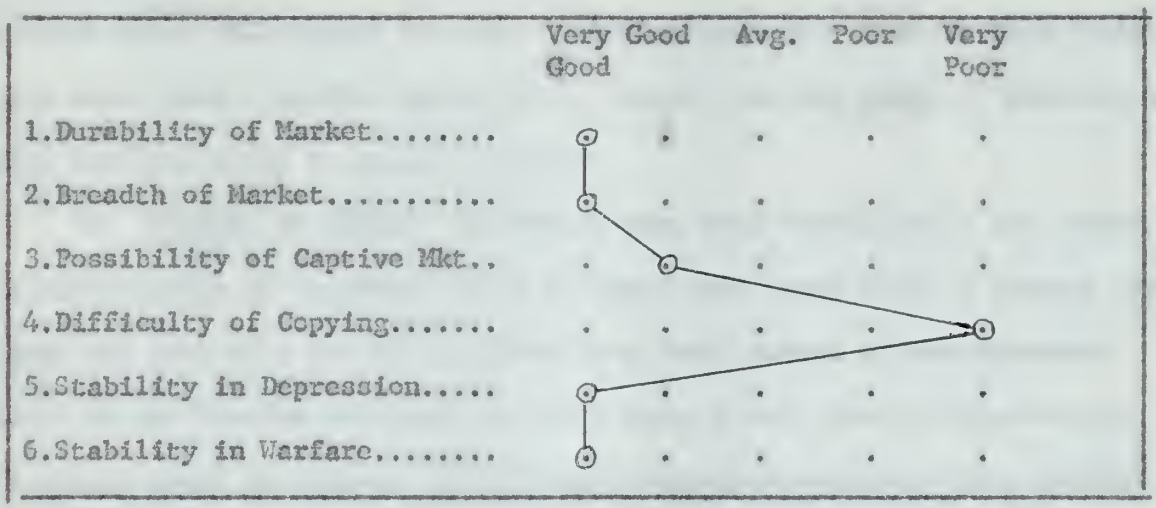
[28] Ibid., p. 24.

FIGURE 4

CHART OF STABILITY FACTORS[a]



[a]Theodore T. Miller, "Projecting the Profitability of New Products," The Commercialization of Research Results.

ideas which have profiles showing a large proportion of good and very good ratings are scarce. The grouping and individual factors considered are as follows:

Stability Factors

1. Durability of Market. A basic commodity such as sulfuric acid, for which there will always be uses, would be rated very good on this factor. On the other hand a product going into a textile end use which is starting to become obsolete would be rated very poor.

2. Breadth of Market. A product used both domestically and abroad by a wide variety of customers would be rated very good; while a product used in just one step of a process peculiar to a small number of manufacturers located in the Pacific Northwest would be given a very poor rating--unless this rating could be improved by favorable long-term contracts with reliable purchasers.

3. Possibility of a Captive Market. An average rating would be given to a product for which there is a potential use within the company, but which can be bought from outside suppliers at such favorable prices that the return on investment for company facilities would be borderline.

4. Difficulty of Copying. A product covered by a strong patent and manufactured by a unique process, from intermediate materials produced only by the company, would rate very good.

5. Stability in Depressions. A product distinctly in the luxury class, where purchases can easily be postponed, would be rated very poor, while one that is an essential constituent in staple low-priced consumers' perishables should get a rating of very good.

6. Stability in Wartime. A product which would almost immediately be denied allocations of critical raw materials in wartime would draw a rating of very poor, whereas a product which would be in heavy demand as a replacement for other more critical items would be rated very good.

Growth Factors

1. Unique Character of Product or Process. A product which can fill an important unsatisfied need or that can rapidly-and without interference-replace a higher-priced material should rate very good for this factor.

2. Demand-Supply Ratio. Although the product may not be unique, if there is room for a new supplier because the demand is expected to outgrow the supply, it should rate very good so far as this factor is concerned.

3. Rate of Technological Change. If there is a wave of change looming up on which this new product can ride it draws a rating of very good.

4. Export Possibilities. If the sales growth of the new product can be markedly accelerated by adding export sales to domestic sales, it deserves a rating of very good.

Marketability Factors

1. Relationship to Existing Markets. A product which can be sold to present customers through present sales organization rates very good. A product which requires an understanding of an entirely different field from any the company is selling, or requires an entirely different sales organization, or must be marketed through entirely different distribution channels rates very poor.

2. Company's Reputation in Allied Field. Although prospective customers in a new field may not be the ones to whom the company is now selling, if the company is highly regarded in an allied field it may nevertheless have an advantage, and the product should be rated very good on this factor.

3. Relationship to Probable Competition. If other suppliers have neglected their markets and handled their trade relations badly, the new product gets a rating of very good on this factor. If, on the other hand, the other suppliers not only have served their customers extremely well but buy from these customers as much as they sell to them, a rating of very poor should be used.

4. Company's Ability to Meet Customer Service Requirements. Since the Polymer Chemical Division of W. R. Grace & Company has a modern, well equipped and well-staffed plastics application laboratory, a new product would rank very good if its applications could be studied and demonstrated in the same molding, extrusion, and coating equipment that the company has. If it were a "first cousin"--say, a rubber compounding ingredient--it would rank good; but, if it had no relationship whatsoever to any of the techniques now mastered, it would have to be assigned a rating of very poor.

5. Relationship to Customers' Products. A product would have to rate poor or very poor if it were the same type of product customers make, or if it were a different type but tended to take business away from them or detract from their business profitability.

6. Large Volume with Individual Customers. When customers buy in large volume, selling and servicing expenses will ordinarily be relatively low;

also, the larger customers may have adequate evaluation facilities which could be of importance during the development stage. All these conditions will give the new product a rating of very good, which, to some extent, will offset a very poor rating in the "breadth of market" factor listed under the stability heading.

7. Few Variations or Styles Required. If it is evident that a new product requires a wide variety of grades, styles, and packages which will result in poor manufacturing economies and cumbersome inventories, the product will have to be rated very poor in this factor. This will be especially true if style changes could leave the company with obsolete inventories.

8. Freedom from Seasonal Fluctuations. The product which rates very good on this factor is one that can be made, stocked, and sold at a steady rate all year round. The rating must be lowered as seasonality creeps in, particularly if the off seasons coincide with the off seasons of other products made in the same plant or sold through the same channels.

Position Factors

1. Time Required to Become Established. Company position is more secure if the company completes development work, build facilities, and become established before there are any serious changes in economic, technological, or competitive conditions. The new product which can be commercialized most rapidly, therefore, rates very good on this factor, whereas the one which has a longer, more difficult development period ahead must be rated very poor.

2. Value Added by In-Coming Processing. Company position is more secure-and the new product's rating on this factor will be higher-if the company handles the entire processing rather than acts merely as a converter at one step.

3. Exclusive or Favored Purchasing Position. If the company can absorb the entire output of a scarce and particularly advantageous raw or intermediate material that is produced by a highly reliable contract source the position is more secure than if a competitor has access to the same material.

4. Improved Purchasing Position. If the new product's commercialization steps up purchase of certain raw materials into the carload or tankcar class, or enables the company to contract more favorably for raw materials, a very good or good rating is assigned to this factor.

5. Availability of Raw Materials Within the Company. This factor rates a very good or good mark if a raw material for the proposed product is already made or can be made elsewhere within the company.

Research and Development Factors

1. Utilization of Existing Knowledge. The less the uncharted territory to be explored in the laboratory, the more the chances of a product's success, and the better the rating for this factor.

2. Relationship to Future Development Activities. A project which is closely related to the main lines of the company's future activities and which will broaden the know-how fundamental to those activities will receive a far better rating than one which takes polymer down a side street.

3. Utilization of Existing Laboratory or Pilot-Plant Equipment. This saves time and money and is worth a high rating. The necessity for constructing new research facilities or acquiring and learning to operate large amounts of new equipment swings the rating toward the unfavorable side.

4. Availability of Research and Development Personnel. The unavailability of the right talent within the company and the difficulty of locating it outside (unless it can be obtained by farming out research to university or consultant laboratories) is a factor to be weighed carefully and rated accordingly.

Engineering Factors

1. Reliability of Process Know-How. Many a new project runs well over its original cost estimate because the difficulties of developing an untried process step were underestimated.

2. Utilization of Standardized Equipment. If the available process data indicate that standard equipment will fit the process, the element of risk is reduced, and the rating on this factor can be a high one.

3. Availability of Engineering Personnel. The same considerations which were rated in the case of research and development personnel are also applicable here.

Production Factors

1. Utilization of Idle Equipment. The advantages of this possibility are obvious.

2. Utilization of Surplus Steam, Electric, and Water Capacities. The surplus utilities should be reviewed as to possible future demands on them

and, if truly surplus, should be considered a strong plus value in rating the new product on this factor. If, on the other hand, the new product would fit only into a plant where expansion of water supply, for instance, would be very expensive, it would receive a very poor rating on this factor.

3. Utilization and Upgrading of By-Products. There is an obvious advantage if this situation exists.

4. Utilization of Processes Already Familiar to Company Personnel. The high cost of training employees in new processes, where necessary, warrants a poor or very poor rating.

5. Availability of Production and Maintenance Workers. If the new product is being considered for manufacture at an existing plant, both the quantity of labor available and the new categories of jobs required should be weighed and rated.

6-8. Freedom from Hazardous Operating Conditions; Difficult Maintenance Requirements; and Waste Disposal Problems. All three of these factors will, of course, be estimated quantitatively when the operating costs are projected, but they also deserve a qualitative appraisal during the screening process.

The total profile for the new product idea covers 38 factors. If the idea shows a good profile, then the company is ready to do further evaluation on it. In this way, attention is concentrated on proposals that have survived the screening, and efforts are not diluted by pursuing lengthy studies on those that should be discarded or shelved.

After preliminary ratings have been confirmed or modified favorably, a quantitative profitability analysis is begun. Polymer does not seem to have any magic formula for appraising profitability to the last degree. Conventional gauges, such as return on investment, cash-flow analysis, pay-off period, and break-even analysis, are used extensively. The company also tries to make the same estimations for competitors to see whether they may be showing any particular advantages or disadvantages. Realistic cost estimates and profitability forecasts are worked up to be used in the final consideration of project proposals. Sound decisions are reached based on all the factors to be considered with the decision being made only after study and recommendations being made by the new product planning team composed of personnel from every phase of the organization.

CHAPTER III

FINANCIAL CONTROLS

The Budget

Control has been defined as the regulation of business activities in accordance with the requirements of business plans.[29] In the area of research and development, dollar planning and control procedures are as valid as in any other phase of business, in spite of what some research personnel may say and feel. Many researchers do not understand the need for some type of formal controls on research expenditures, and are sometimes found devising ways and means of subverting control procedures on the basis that they hinder the scientist's creative work. This need not be so. Controls can and should be implemented in such a manner that researchers are not restricted in their approach to the problem. It is true that overplanning can stifle creativity and originality and be damaging to the entire program. But this fact does not mean that no plan or control procedures should be utilized. It may mean, however, that varying degrees of control are exercised in various phases of research and development. There seems to be general agreement that basic

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[29]Marvin, p. 54.

research is best performed with almost complete freedom from organizational controls, while applied research and development programs may be controlled in some detail. It follows then that detailed financial controls reach their zenity as the production end point is approached. Fortunately, this follows expected fund expenditures as greater sums are expended in the latter phase than in any other.

In general, therefore, financial plans should be prepared in such detail as is required to accomplish the assigned task with the best possible use of available funds without stultifying research creativity. Even though only the empirical elements of research can be planned with any surety, a plan and schedule of the entire project are of value if only to provide a requirement of definite forethought and in providing a track to run on and to measure progress by. Often, the guesses aren't too far off and plan and schedule are then of real value.

In the previous chapter, interest was centered on defining the planning procedures which provide the upper limit for overall research expenditures and the probable costs of individual projects. Although the total amount of the budget for research and development is the first major premise for budgetary and cost control, the allocation of specific funds and the rate at which these funds are utilized are not specified merely by determination of what funds can be made available. Consequently, the detailed planning and control of expenditures required by a research program are separate and important aspects of financial management in research and development.

The establishment of a detailed budget provides a guide for the research department to use in programing their efforts. Such guidance is invaluable for those who must make the decisions, direct the progress of the research program, and control the expenditure of funds allocated to research projects. No other planning device offers the advantages of a properly prepared budget. It allows managers to sum up the detailed plans for each project underway and to see their aggregate impact in a common denominator--dollars. It would be extremely difficult to express detailed and technical research plans to uninitiated management in terms of engineering requirements, technical progress schedules, and innumerable other input factors. A budget also assists in developing a balanced research program since management can easily see in relative terms the amount of research supporting each product line and the balance between expenditures being made on each phase of research and development. A final advantage of a research budget is that it forces management periodically to pause and plan concretely its research program. It automatically brings the whole program up for a periodic review. This keeps the program from rolling along indefinitely without replanning, which might lead to disjointed research and development efforts completely out of step with company goals.

To gain these advantages companies should develop careful research budgets to assist in effecting optimum utilization of available resources and facilities. However, budgets in themselves are not a means of control but must be coupled with financial reporting for this purpose. Comparison of actual performance with predicted performance gives management a means of

exercising control in those areas which require it. In view of the above, it is evident that there are two phases to financial control of research and development programs, preparation of the detailed budget and financial reporting.

Types of Budgets

There are two major types of budgets in general use by research organizations. These budgets are (1) organizational budgets, sometimes referred to as expense classification budgets and (2) project budgets. There is a third type of budget used by some organizations but is not in general vogue. This type is termed the capital expense budget. Organizational budgets are overall research budgets prepared for individual research organizations which present contemplated expenditures by type of expense, and which permit managers to provide for facilities and staff in accordance with the amount of money available. They may be fairly simple in form but, if a comprehensive budget is desired, can become quite involved. The degree of complexity depends on the size of the research organization, the amount of money involved, and the amount of information and control desired by management. A basic budget may consist of (1) payrolls and related matters such as social security taxes and other items, (2) supplies and materials, and (3) other direct operating costs.[30] Such a grouping may be adequate for the small or medium-sized organization, but for larger ones these classifications may be broken down into considerable detail to present a more comprehensive budget and provide better control. Figure 5 shows a typical organization budget.

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[30]Adolph G. Lurie, "Controlling Research Costs With A Budget," National Association of Cost Accountants Bulletin, XXXIV, July, 1953, pp.894-901.

FIGURE 5

RESEARCH AND DEVELOPMENT DIVISION

ORGANIZATIONAL EXPENSE BUDGET

(Year Ended December 31, 1953)[a]

1. Payroll	
a. Technical employees	$150,000
b. Non-technical employees	30,000
c. Service employees	20,000
d. Plant labor	10,000
Subtotal	210,000
2. Supplies and materials	
a. Expendable equipment	25,000
b. Operating supplies	15,000
Subtotal	40,000
3. Other direct costs	
a. Books, dues, subscriptions, etc.	5,000
b. Travel expenses	15,000
c. Technical, engineering, and consulting fees	15,000
d. Taxes, insurance, depreciation	5,000
e. Light, heat, power, etc.	5,000
f. Miscellaneous	5,000
Subtotal	50,000
TOTAL BUDGET	$300,000

[a]Adolph G. Lurie, "Controlling Research Costs With A Budget," National Association of Cost Accountants Bulletin, XXXIV, July, 1953, p. 897.

Project budgeting is the more important phase of research budgeting for cost control purposes. A project budget showing planned costs is prepared for each project to be undertaken or which is already underway during the budget period. They too can be relatively simple or quite elaborate, depending on the degree of control desired. The simplest procedure would be merely to list the projects contemplated and the dollar amounts to be allocated to each. It should be recognized that the budgeted dollars here are the same dollars as those found in the organizational budget. The total amounts authorized for all projects must agree with the total budgeted by class of expenditure in the organizational budget. A more detailed approach to project budgeting is illustrated in Figure 6. This form makes provision for additions of new projects to the list during the period as new ideas are accepted for development; provides funds to continue projects already underway; makes provision for operating the research service department; and apportions remaining funds to individual projects being considered. No attempt is made to show the manner in which funds are to be expended since the amount of labor, materials, or supplies cannot readily be determined beforehand. Efforts to pinpoint expenditures to the extent that a figure for expense classification within each project is developed might so limit the research organization as to interfere with its smooth functioning. Project budgets must be complemented by organizational budgets, particularly when the research effort on a specific project is spread among several organizational units. Since the administration of the research program is by organizational unit, project budgets may be inadequate control devices in these cases.[31]

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[31]Some large companies have several research units or divisions within their organization. In the Minnesota Mining and Manufacturing Company each product division has its own research and development organization.

FIGURE 6

RESEARCH AND DEVELOPMENT DIVISION

PROJECT EXPENSE BUDGET

(Year ended December 31, 1953)[a]

	Current Budget	Prior Expenditures	Total Authorized
1. Present products			
a. Projects in progress			
(1) Products x improvements	$ 5,000	$15,000	$20,000
(2) Product y usage	10,000	10,000	20,500
(3) Product z quality	10,000	7,500	17,500
Subtotal	25,000	33,000	58,000
b. New projects			
(1) Product x new process	25,000		25,000
(2) Product y quality control	30,000		30,000
(3) Product z new use	20,000		20,000
Subtotal	75,000		75,000
Total present products	100,000	33,000	133,000
2. New product research			
a. (1) Product xx	15,000	12,500	27,500
(2) Product yy	10,000	5,000	15,000
Subtotal	25,000	17,500	42,500
b. New projects			
(1) Product P	30,000		30,000
(2) Product Q	25,000		25,000
(3) Product R	10,000		10,000
Subtotal	65,000		65,000

FIGURE 6 CONT'D.

	Current Budget	Prior Expenditures	Total Authorized
Total new products	90,000	17,500	107,500
3. Pure research			
a. Projects in progress			
(1) Item S	5,000	3,500	8,500
(2) Item T	7,000	3,000	10,000
Subtotal	12,000	6,500	18,500
b. New projects			
(1) Item U	3,000		3,000
(2) Item V	5,000		5,000
Subtotal	8,000		8,000
Total pure research	20,000	6,500	26,500
4. Sales department service			
a. Projects in progress			
(1) Product x	7,000	1,000	8,000
(2) Customer z	3,000	1,500	4,500
Subtotal	10,000	2,500	12,500
b. New projects			
(1) Product y	2,000		2,000
(2) Product q	3,000		3,000
Subtotal	5,000		5,000
Total Sales Department service	15,000	2,500	17,500

FIGURE 6 CONT'D.

	Current Budget	Prior Expenditures	Total Authorized
5. Service departments			
a. Library	10,000		10,000
b. Drafting room (general)	5,000		5,000
c. Stenographic and clerical	10,000		10,000
Subtotal	25,000		25,000
6. Balance for unauthorized projects	50,000		50,000
	$300,000	$59,500	$359,000

[a]Adolph G. Lurie, "Controlling Research Costs With A Budget," National Association of Cost Accountants Bulletin, XXXIV, July, 1953, p. 498.

Capital expense budgets are utilized by some companies in order to program expenditures for expensive laboratory equipment. In many instances, such equipment is not directly chargeable to an individual project but is budgeted for separately.

The relative use being made of these budget types by research organizations is indicated by the results of the Harvard University Research Control Survey.[32] In large organizations having more than 125 employees about 80 per cent reported that they used both project and organizational budgets with the other 20 per cent reporting use of project or organizational budgets only. These figures are significant in the fact that some method of financial control is apparently considered to be essential by all of the larger research organizations participating in the survey.

Budget Items

Research costs must be measured on a consistent and well-defined basis before they can provide meaningful data for control decisions. Only those items which are truly research and development costs should appear in the research budget. This fact appears self-evident yet at the same time, "some items seem to find their way into the research budget even though they do not belong there."[33] An example of this type of expense is the technical advice or assistance given to the production department to help it out of some

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[32]Anthony, p. 140.

[33]Edward P. Burnham, "Controlling the Costs of Research," The Management Review, XLVII, August, 1958, p. 21.

difficulty. All work of a service nature should be charged to the department for which the service was performed.

Also must be decided is the question of when research responsibility, and, therefore, research costs, ends. Any one of a number of cut-off points can be used, such as the point at which production accepts the process or when the pilot plant produces the initial batch of products. The important thing to consider is that some clear-cut point in the progress of product development must be firmly established as the juncture where research costs end and production costs take over.

There is a large number of actual research costs which can be properly budgeted, with the number of items being budgeted dependent on the interests of the individual organization. As set forth in Chapter II, there are three primary categories of project costs. These are (1) salaries and wages, (2) materials and supplies, and (3) overhead costs.

The largest single item in the research and development budget is usually salaries and wages. It is relatively simple to develop these dollar amounts by totaling the salaries and wages to be paid to the personnel directly engaged in research work. An estimate of plant labor required for operation of the research effort can also readily be made based on past experience.

The amount for materials, supplies and equipment can also be based on past usage figures after adjusting for variations in program size or other variables.

Overhead costs can be determined by examination of the various items involved. Direct charges to the research organization such as technical

books for the research library, travel to technical society meetings, consulting fees, etc. can be estimated with a considerable degree of accuracy. Such items as taxes, insurance, utilities, and other similar expenses can be fixed by the distribution of the total company cost to the individual departments on some previously determined basis such as square footage of space occupied.

Budget Formulation

Frequency

The Research Control Survey indicated that 80 per cent of the companies surveyed which prepared research budgets do so annually.[34] Although budgets for a shorter period can be made more accurately than those prepared for a year ahead, the work involved in more frequent preparation is not generally believed to justify the use of budgeting periods of less than a year. Changes in the budget can be made as required during the year even though "the budget" is prepared annually.

Who Prepares the Budget?

Persons experienced in budgeting work are in general agreement that budgets are more effective when the original estimates are prepared by or under the direction of the person who is to be held responsible for performance. The type of budget which is least effective is the "imposed" budget which is prepared by top management and transmitted to department heads

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[34]Anthony, p. 146.

within a division in the form of an order. In violation of this concept of proper budget formulation, the Research Control Survey[35] indicated that in only 47 per cent of the companies surveyed were budget estimates prepared by the department head and that in a few other cases the estimates were prepared by someone in the department. But in almost half the laboratories surveyed the estimates were prepared by management at a higher level than the department head. In some companies in the latter category the department head was consulted about the estimates, even though he was not responsible for preparing them.

Staff units, such as the accounting department, the budget department, or the controller's department, are very likely to participate in the process of preparing budget estimates along with department heads, committees, and higher management.

Review and Approval

In nearly all companies the research and development budget goes to top management for review and approval. Top management is usually more concerned with the total of the budget and the amounts being spent in the principal research areas, rather than in amounts being spent on specific items in individual departments.

Even in the review which takes place within the departments, more attention is usually paid to totals rather than individual items, unless there

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[35]Anthony, p. 148.

is a drive on to eliminate certain expenses or certain items show large variations from previous expenditures. This differs from normal factory procedure of carefully scrutinizing individual items to determine possible areas of reducing budget estimates. The essential reason for this difference in procedure is the fact that in the factory good measuring sticks exist which can be used to test the validity of specific items, while in the research department there is no comparable and valid means available for testing individual items on a budget estimate due to the uncertainty and unschedulability of research work.

Revisions

The Research Control Survey indicated that almost a third of the companies participating did not revise their budgets at all during the budget period.[36] Since it is hardly likely that the spending in these companies actually conformed to budget estimates, the implication is that budgets are not always changed to reflect changes in proposed spending. The prevalency of companies not making periodic budget revisions as required by changing situations suggests that in many companies the budget is not looked upon as an important control device or progress measure.

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[36] Ibid., p. 154.

Accounting and Reporting

The provision of funds for the overall research and development program, the control of individual projects within budgeted funds, and the general control of costs are closely related. Under a budgetary plan of control, it is self-evident that expenditures must be related to the budget for control purposes. This is accomplished by implementing cost accounting and internal financial reporting procedures designed to provide management with the information it needs to make comparisons between actual expenditures and those authorized. Only when this is done is a budgetary control system of value to management in making decisions and controlling the research and development effort along the lines dictated by company objectives.

Cost accounting and reporting should not be contemplated as a mechanism for reducing research expenditures. The allotment of the proper amount to the research program should have already been determined by top management prior to the compilation of cost data required for control. Cost control should rather be viewed as a basic form of assurance that authorized funds are spent for productive research and development or are saved, and are not diverted into nonproductive channels of investigation. This is particularly true in the area of nonresearch service costs performed for other departments within the company. The net effect of such control is to make more funds available for research expenditures in the long run and to provide added assurance that if management is willing to provide funds for research an adequate accounting for such funds will be rendered. In most companies this type control is considered mandatory for general expenditures.

The same principles of cost control used in effective management of manufacturing and sale of products can also be used in controlling the expenditures for research and development. Research monies need not be considered different from general expenditures and can be subject to a similar degree of control.

Cost accounting systems can be very simple or very detailed depending on the type of organization, degree of information desired, and the benefits to be derived from the cost accounting information. Mees and Leermakers[37] present the following factors which influence the degree of complexity of the cost reporting system: (1) the size of the research organization, (2) the relation of the research department to the company organization, (3) the accounting detail in use in the company as a whole, and (4) the cost of obtaining the information. These factors are self-explanatory but it should be noted that the amount of accounting detail in general use throughout the company probably has the greatest effect on research cost accounting. Research accountants are usually under the supervision of the company's accounting department and most likely would follow the same general policies that guide accounting in other departments.

Classification of Costs and Cost Accumulation

Cost accumulation and cost classification procedures should be such that they meet management requirements at all levels of authority. Obviously, the same classification of costs will be used for budgeting as well as

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[37]Mees and Leermakers, p. 303.

reporting current expenditures. Burnham[38] suggests the following areas of management interest as a basis for devising a classification of accounts.

1. The total spent for research. A total amount of funds expended on the research effort can be obtained by having a single account to which all research expenses are charged. For purposes of segregating expenses attributable to individual laboratories all that is needed is the addition of an additional code number to the basic account number which will identify the laboratory or unit incurring the expense.

2. The cost of individual projects. The total expense for any project can easily be determined by merely assigning a project accounting number to each project and charging all expenses to it.

3. The cost of items making up the total expense. Usually, the same expense elements, codes, or accounts that are used by other departments in the company can be used for these costs. However, it is probable that some expenses peculiar to research will require special accounts. Use of these accounts permits management to determine the total expense by element of cost for all projects and for each individual project.

4. The organization or unit which spent the funds. By simply assigning a code to each organizational unit or subdivision, management can identify the spender.

5. Expenditures by phase of research and development. Expenditures may be made for work in applied research, pilot plant research, new methods and techniques, or any number of other areas. Classification of costs by

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[38]Burnham, The Management Review, XLVII, p. 24.

assigning code numbers permits determination of the amount spent in each phase of research and development work.

6. Expenditures by type of research. This is a broader classification than that by phase of research. This classification permits identification of costs with basic research, new product development, or in support of present products. Coded accounts show management exactly how research efforts are being apportioned between present and future.

7. Expenditures by individual products. When companies have several product areas it may be desirable to know the expense associated with each product. Classification of projects according to product areas provides a means of obtaining this information. Those research efforts applicable to more than one product area or those of a general nature which benefit all areas can be charged to a special account and later prorated to individual product areas.

By taking these areas of management interest into account, as well as any others which might be of value to a particular company, a satisfactory plan for coding and classification of research expenditures can be developed. A typical project classified under such a classification system is shown in Figure 7.

With information furnished by such a classification of accounts, the accounting department can prepare reports which furnish short-term records that management can use for day-to-day decisions; which can serve as a starting basis for budgets; and which furnish a long-term record of costs by projects, elements of cost, type of research, or other needed information.

FIGURE 7

TYPICAL CODING OF RESEARCH COSTS[a]

Question	Heading	Assigned Code Number
Total spent for research?	Department	412
Cost of individual projects?	Project Number	2983
Type of expense element?	Expense Element	218
Unit which spent funds?	Unit	34
What phase of research?	Phase of Research	12
What type of research?	Type of Research	02
Expense for each product?	Product Area	07

Expense code would appear as: 412 - 2983 - 218 - 34 - 12 - 02 - 07

[a]Edward P. Burnham, "Controlling the Costs of Research," The Management Review, XLVII, August, 1958, p. 81.

The accumulation of costs in research and development departments does not vary significantly from the cost accounting procedures that are employed by other departments within the company for this purpose. The general method for accumulation of direct labor costs is through utilization of a time card or record. The individual cards of personnel assigned to a project are accumulated into dollars by the standard procedure of applying specific hourly rates. The extent of usage of this procedure can be seen from the data compiled by the Research Control Survey.[39] The survey indicated that 96 per cent of the participating companies having over 125 employees used time records as the basic element for accumulating labor costs. Records were normally made out by individuals as evidenced by the fact that 88 per cent of the companies so reported. Another significant fact was that 43.7 per cent reported that records were prepared weekly with 35.2 per cent reporting monthly preparation. These facts may provide a clue as to the accuracy of labor charges and the degree of control being exercised in most research organizations.

Material costs are usually accumulated in the same manner as their production counterparts. For example it is common practice to utilize both purchase and inventory requisitions. The requisitions are identified by account codes with the organization or project which requires the material. The amount of detail with which materials accounts are kept varies greatly with individual organizations. Some companies charge only items of considerable expense to specific projects while others allocate costs of

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[39]Anthony, p. 176.

materials costing as little as one dollar to specific projects.

Overhead costs are readily accumulated by use of time cards and purchase records. However, proportionate distribution of these costs to units and projects represents a significant problem. The mode used to accomplish this varies widely but the most general practice seems to be to lump all overhead costs as one sum and to allocate them to individual units and projects based on the direct labor charge. Accounting procedures enabling the charging of overhead costs to projects or units in the exact amounts which were utilized would appear to be too costly to warrant their application in most instances.

Research Cost Reporting

The need for proper reporting of costs and expenditures to management is obvious. The ultimate purpose of accumulating costs is to permit the comparison of actual spending with that authorized by the budget in order to give effect to financial control in the research and development program.

The essential features of good spending reports are the same as those of managerial reports generally. They should be clear, simple, timely, and accurate, and should contain only that information which is required. The level for which costs are expressed in financial reports should obviously be the level at which responsibility for control of the research program lies.

The frequency of financial reporting is expressed in the Research Control Survey previously referenced.[40] Of the 302 research organizations

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[40]Anthony, p. 174.

which participated in the survey, 58.6 per cent reported costs on a monthly basis with an additional 17.6 per cent reporting on a quarterly basis. Whatever frequency is used should depend on the usefulness of the reports and should be commensurate with the requirement for degree of control and the costs of preparing the reports.

As might be surmised from the fact that there are two types of budgets generally used, there are two types of spending reports also in general use. These are reports by organizational unit and by project. Figures 8 and 9 are examples of the two types of reports.

Management Use of Budget and Cost Reports

The evaluation of research output is a highly complex problem and will be treated in the following chapter. It is unfortunate that accounting techniques can offer little help to the evaluation problem except to focus attention on the costs of the research progress that has been made. Management can readily predict that x number of man hours will be expended in y weeks investigating a research project. But management cannot say whether any profitable results will have been attained by the end of the programed time. Consequently, comparing budgets against cost accumulations merely shows whether planned effort is going as prescribed, not whether planned results have been achieved. In the final sense, budget and cost comparisons measure effort, not progress.

Management can and does use budgets as check points to measure fund expenditures. Quinn[41] presents this analysis of the way such controls

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[41] James Brian Quinn, "Control of Research and Development Costs," The Journal of Accountancy, October, 1960, p. 55.

FIGURE 8

EXPENSE STATEMENT AND BUDGET COMPARISON PROCESS

DEVELOPMENT DEPARTMENT, MERCK AND CO., INC.[a]

	Monthly Budget	Current Month	Year to Date		
			Budget	Actual	Variation
Payroll Expense					
Professional--Direct					
Professional--Overtime					
Hourly--Direct					
Hourly--Overtime					
Cost of Living Adjust					
Total Payroll					
Controllable Expenses					
Supplies					
Materials					
Repairs					
Travel					
Telephone					
Laundry					
Outside Services					
Publications					
Chemical Control					
Total Controllable					
Non Controllable Expenses					
Losses, Abandon, etc.					
Total Non Controllable					
Total before charges to Others					
Charges to Others					
Overall Total					

[a]R. N. Anthony, Management Controls in Industrial Research Organizations.

FIGURE 9

COST OF WORK

BELL TELEPHONE LABORATORIES, INC.[a]

	Current Period				Cumulative Period				
	This Period	Diff. from last Period	Diff. from Budget	% of Budget	This Year	Diff. from last Year	Diff. from Budget	% of Budget	Year's Budget
Salaries and Related Costs									
Materials and Supplies									
Services Purchased									
Depreciation									
Other Costs:									
Traveling									
Rentals									
Real Estate									
Taxes									
Miscellaneous									
TOTAL									

[a]R. N. Anthony, Management Controls in Industrial Research Organizations.

operate. The controller usually notifies responsible management when a certain percentage of project funds is expended. This percentage may vary from 75 per cent of the project budget in some companies to 105 per cent in others. Before the research project can proceed further, more funds must be approved after considering the project's progress and potential value versus its cost. Thus project budgets provide a means for automatic project reviews with certain side benefits such as forcing researchers to plan more carefully, be more cost conscious, and to recognize that they must demonstrate definite progress if they are to be given more funds to continue a project. Within reason, cost consciousness can make definite contributions to research progress but management must be careful not to use budgets as a club over researcher's heads.

Comparing actual expenditures against those budgeted also serves to assure management that the research program's intended emphasis is being carried out. Without such checks management would have no way of knowing whether researchers were working in the areas which the initial development of the program intended or were busily pursuing their own personal interests in other areas.

Primarily then, budgets and cost reports serve management as a means of focusing attention on those areas where actual expenditures deviate significantly from budgeted amounts. Deviations may mean that replanning and redirecting of research efforts may be warranted. Analysis of costs versus budgets in no sense will serve to measure actual progress being made on research projects.

Variance Interpretation

Accounting procedures employed in research and development make it possible to develop what Quinn chooses to call: (1)"volume variances" showing deviations of actual costs from those budgeted for overhead costs, (2) "efficiency variances" demonstrating how much more or less money than was budgeted was spent on each project during a given period, and (3) "price variances" indicating how changes in plans affect project and organizational costs.[42]

In the first instance, volume variances are directly related to the overhead absorption plan followed. If overhead is absorbed on a direct labor basis, variances are likely to mean that research personnel could not be hired at the desired rate or that the actual number of personnel planned for was not realized. They rarely mean that overhead costs have fluctuated violently. If overhead costs are allocated on a square footage of space basis a similar situation pertains. Individual research activities are of a diverse nature. This results in an extremely fluid space requirement making it very difficult to accurately allocate space charges to individual projects. As a result, variances in overhead costs when this method is used are of little use. Quinn suggests that perhaps the most efficient way to budget and analyze overhead is as a lump sum not related to any base. Then the actual cost of each item can be compared with budget estimates of what the costs should have been. However, this method would appear to entail some

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[42]Quinn, Yardsticks for Industrial Research, p. 74.

rather costly accounting records. Management would have to measure this cost against the value expected to be received from having such details readily available in order to indicate the reason for overhead variances.

Efficiency variances relate primarily to departures of labor charges from budgeted labor costs. However, as pointed out in the preceding section, labor efforts expended on a research project cannot measure efficiency. Consequently, analysis of labor time variances become no more than comparisons of total labor time expended during the period against estimated labor expenditures for that period. Too, increases or decreases in wage rates would cause variances. Thus, the only valid conclusion that analysis of such variances would provide is that personnel originally scheduled to work on the project were or were not assigned to it. In the phase of applied research, where projects may be of a nature that the specifications of the desired product can be completely defined and the work is such that experience in similar projects provides a sound basis for forecasting costs, budget variances are more effective measures of efficiency. Unfortunately, in most research projects such forecasting is not feasible--uncontrollable factors have a great effect. Consequently, efficiency variances cannot be interpreted in research and development in the usual cost accounting sense. They do, however, serve a useful management purpose. Significant variances should act as a red flag, indicating areas to management where questions might be raised about the activity on these projects. Under-or over-expenditure may indicate changes of emphasis that management should know about. In effect then, efficiency variances do not adequately measure research efficiency but they do provide assistance in steering research efforts in the right direction.

Price variances are differences between actual and planned costs of time and materials brought about by changes in plans. They are perhaps the most meaningful of the variances developed by standard techniques for they permit managers to measure the cost of their changes in plans. If more expensive equipment is required, these increases would be apparent and would allow nontechnical managers to raise pertinent questions. This helps in keeping the research technical managers on their toes and forces them to be constantly considering the relative costs of alternative approaches.

It has already been pointed out that forecasting of research costs cannot be precise. For this reason, management of research organizations cannot afford to interpret variances in any rigid manner. Staying within a total research budget does not mean that research and development operations are efficient or well managed. Nearly all research executives could stay within their budget simply by hiring or not hiring people. Such a procedure could be extremely costly. The objective of research is to produce technology at a rate compatible with the company's growth plans. Management should be more concerned with the rate research results are coming out rather than 4 or 5 per cent variances in expenditures. The main value of analysis of budget variances is to warn management that it may be necessary to reappraise the current research and development program's scheduled commitment rate.

A Typical Control Operation

This section has been incorporated in order to demonstrate the actual application of budgeting and reporting procedures in a specific research

organization. Merck and Company, Inc. typifies the general research organization which has the usual research problems of determining the overall expenditure limitation, selecting individual projects, and controlling research operations.

Merck and Co., Inc.[43]

Merck and Co., Inc. is one of the country's largest manufacturers of fine and medicinal chemicals, with sales of over $200,000,000 in 1960. Its research division was organized in 1933, and provides modern facilities for research and development in the fields of chemistry, chemical engineering, microbiology, and biochemistry. The company pioneered in vitamins, sulfa drugs, penicillin, streptomycin, and other new products which represented tremendous advances in medicine and chemistry. At the end of 1951, new products from its research organization represented over 75 per cent of total sales.

Laboratory Organization

Merck and Co.'s laboratory is a relatively large one, employing about 850 personnel in 1952. The senior executive of the research and development division is the vice president for research and development. He reports to the vice president and scientific director, who is also responsible for the chemical control division and the medical division. In the research and development division, all departmental directors report to one of three

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[43]R. N. Anthony, Management Controls in Industrial Research Organizations, pp. 169-185.

associate directors who, in turn, report to the vice president for research and development.

Project Planning

The word "project" is used at Merck and Co. as an all inclusive term to refer to all research and development planning and work on a project. Much of the work planning centers around the preparation of the financial budget. About the first of September the vice-president for research and development starts the budget process for the coming year with a group meeting of the associate and departmental directors. At this meeting the status of each active project is discussed and tentative plans are discussed for the coming year. Each participant in the meeting then discusses new projects which he believes should be instituted during the next budget period.

From knowledge of the scope of activities in other departments, and his visualization of problems to be solved, each departmental director projects the manpower workload he expects in his department for the succeeding year. First, he prepares a preliminary description of the projects on which he plans to have the department work. This is a fairly rough statement and no dollar figures are projected. The departmental director and his associate director then discuss these projects and arrive at a tentative understanding as to the projects to be undertaken. The departmental director then makes a distribution of the manpower expected to be available. The departmental director also makes dollar estimates of any unusual equipment, etc. required which are reviewed by his associate director.

The vice president for research and development then has all departmental estimates for manpower compiled and from these statistics he prepares a master distribution of manpower for the entire division, looking at it in terms of the relative emphasis which he believes should be placed on different projects.

The tentative program is then discussed at a meeting presided over by the vice president and scientific director. On the basis of this discussion the program may be modified and tentatively approved by the vice president and scientific director.

Budgeting

The process of determining how much manpower is to be expended on each project is completed by approximately October 10. The next three weeks are spent in converting manpower estimates into dollars. This process is carried out principally by the research business manager and his staff. At the same time, project descriptions are put in final form. The conversion of manpower estimates into dollars is accomplished by applying a standard salary rate to the manpower figures. Supplies and other items are estimated by projecting a cost per person developed from past experience.

The business manager sets forth the budget estimates in a number of very detailed schedules, among which are:

a. Estimated total expense for each project, by departments.

b. Departmental expenses broken down by elements of expense.

c. Consolidated total expense for each project for the whole division.

d. A consolidated total research and development division report of expenses by elements.

e. A preliminary production schedule for the pilot plant.

f. A list of overhead items.

These are only a few of the thirteen schedules prepared which show a considerable number of detailed combinations of basic data.

A summary of these budget schedules is then reviewed by the two vice presidents concerned. By November 1, the preparation and preliminary approval of the budget schedules have been completed. The budget is then forwarded to the controller's division which incorporates the research budget in the overall company budget. The research budget is discussed by top management and by the scientific committee of the board of directors before being presented to the executive committee of the board and then the full board of directors for approval as part of the whole company budget. Usually, there are few changes after November 1, as any change involves a tremendous amount of work in adjusting the detailed schedules.

By January 1, the approved budget is received by the departmental directors. It shows them what they are expected to do during the period, what additional positions they are authorized to fill, and the projects they should decrease, stop, or expand, as well as other matters affecting the operation of their departments. This information has been fairly well known to them before the formal budget is received, but the budget constitutes official approval of the program.

The fact that the budget has been prepared and approved, emphatically does not imply that the approved budget is immutable. The company believes it would be extremely unfortunate should such an implication ever develop. The budget is looked upon as a useful description of the general dollar amount that should be spent in each area of the research effort but it is subject to change as conditions change. Provision for recognizing these changes is made by quarterly review procedures, which substantially parallel the process by which the budget was originally put together.

In addition to the operating expense budget, Merck and Co. also uses a capital expense budget for capital items which do not exceed $5,000 each. This budget follows the same channels of development as the operating budget and is also prepared annually. Capital equipment costing over $5,000 per unit is requested individually with the level of required approving authority rising as the sum involved increases.

Accounting

Both hourly and salaried workers fill out their own weekly time sheets. Because of the nature of work at Merck, researchers usually work on several problems in any one week, and their breakdown of time by projects is bound to be somewhat subjective.

Workers may draw any item in stock by signing for it. Items not in stock are requested by standard requisition form which is approved by departmental director or higher level, depending on the amount involved.

Other work which involves direct charges, such as repairs, is requested on the standard work order form used in the company. Whenever

possible all procedures and forms conform to those used by other divisions.

The mechanical part of the accounting is done by IBM. The system is set up to develop charges for four main categories: by departments, by divisional projects, by individual department project, and by charges to company divisions outside the research division. Code numbers are used to designate charges.

Costs are collected for each project. The time of all persons in a department is charged directly to each project. Projects are also charged with a share of departmental administrative and other direct departmental costs. Projects are credited when the division performs services for other divisions or for persons outside the company.

The research and development account is charged with actual usage costs for certain overhead expense items incurred in operating the laboratory such as steam, heat, and similar measurable items which can be charged directly on the basis of actual consumption. In addition, the division bears a prorated share of those other overhead costs which cannot be charged directly on a usage basis.

Reporting

Research and development executives use three major monthly reports; two of them, the departmental expense report and the project expense report, are based on accounting information and the third is a progress report.

Most departmental directors believe that the report that shows departmental expenses by category of expense is the most useful spending

report for control purposes. This report is designed to show variations between actual and budgeted expenses.

The second accounting report, the project expense statement, is designed in the same manner. Both amounts that are significantly over and those that are significantly under budgeted amounts are examined. A large underexpenditure is just as important as an overexpenditure since it may indicate that not so much work has been done on the project as was originally planned. This may be a serious deviation in the overall scheme of company operations and must be investigated.

There is also a monthly report which reflects the departmental director's explanation of major variances between budgeted and actual expenditures on projects. It goes to both the vice president for research and development and the vice president and scientific director for their consideration.

Complete accounting reports usually reach the research and development division about ten days following the close of the monthly accounting period. The business manager in the meantime obtains complete IEM runs which show the detailed items charged to the various expense accounts and projects each month, and thus is prepared to explain or investigate questionable charges.

In addition to the foregoing accounting reports, the controller makes up a summary of accounts. This is a list of costs by project and by element for nonproject expenses for the current month and the period to date. It shows gross cost, credits, and net costs.

The third major report is primarily a technical progress report which sums the progress made monthly on the projects of the program. These project reports are consolidated monthly at the department level, with a full divisional report on all projects being made quarterly to the vice president and scientific director. This report is then used in conjunction with the quarterly review of the budget.

It is interesting to note the tremendous amount of planning which goes into the preparation and use of the operating budget at Merck & Co. The process of preparing the annual budget and the quarterly reviews thereof requires that all information available be carefully studied. The necessity for balancing work to be done against resources available usually results in eliminating a number of marginal projects and concentrating efforts on those most likely to be beneficial.

CHAPTER IV

EVALUATION OF RESEARCH RESULTS

Current Techniques

Sometimes the results of research are reflected in products or processes so outstanding as to leave little doubt that they have contributed in a large measure to the success and the profits realized by the company involved. This situation is the exception, however, rather than the rule. More likely, research results are hidden in the inner workings of products and processes, and in their interrelation with production, sales and other departments. Research is without doubt profitable but results are not easily measured.

In spite of this difficulty, some form of research evaluation has a very definite place in the programing of the overall research effort and serves several important purposes:

1. It acquaints that portion of management which is responsible for the allocation of funds to the research program with the value of research expenditures.

2. The "credits" accruing to the research organization provide a stimulus to the entire research organization.

3. It shows whether or not research expenditures are out of line with actual benefits to the company.

With respect to the last broad purpose listed above, the following economic criteria are pertinent:

1. Is research successful in preserving the profits of current products?

2. Does research aid in improving earnings and return on investment through improvement of existing products?

3. Does it aid in expanding sales and earnings as a direct result of the introduction of new products?[44]

Evaluation of research is basically the process of judging a company's past performance in research and relating it to the definition of the company's long-range growth goals and profit objectives.[45] Nearly all companies attempt to evaluate the results of their research programs in one fashion or another. The techniques in use vary to a considerable degree--some

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[44]Darrell H. Voorhies, The Co-ordination of Motive, and Money in Industrial Research (Standard Oil Company of California, 1946), p. 62; Charles W. Walton, "Today's Research--Tomorrow's Profits," Critical Areas in Top Management Responsibility, General Management Series, Number 166 (New York: American Management Association, 1953), p. 16.

[45]There are as many definitions of research evaluation as there are authors on the subject. Some consider it to be the overall process of planning, selecting, and controlling projects. Others consider it to be close to the definition stated by this writer, but usually throw in other considerations such as efficiency in attaining results, etc. It is a foregone conclusion that research efficiency cannot be truly measured. For this reason, research evaluation should be thought of, at least in profit-making organizations, ultimately in terms of contribution to growth and profit objectives. Side benefits such as public welfare, good-will, etc. are incidental to the real purpose of industrial research.

are quite formal and quantitative while in other instances they are extremely informal and qualitative. In general, there does not seem to be any real consensus as to an adequate solution to the problem, though most companies and writers admit to the fact that all evaluation factors cannot be readily quantified. Qualitative judgments seem to play a large part in evaluating program results. Current evaluation systems generally follow one of three themes: (1) the quantitative approach, (2) the qualitative approach, and (3) the integrated approach.[46]

Quantitative Methods

The search for a successful measure of research output seems to have been directed in earlier years towards a single, quantitative, objective formula with which management could measure research results in the aggregate. These efforts have been nearly as fruitless as a search for a single measure of sales or production performance would be. Despite this fact, quantitative techniques dominate the literature on research evaluation. The quantitative approach seeks to evaluate the results of the entire research program and to define its total contribution to the company in financial terms by means of a single mathematical formula. The formula can relate to one or more of any number of factors depending on those which management selects. A few of the more common factors used are (1) profits from new or improved products,

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[46]James Brian Quinn, Yardsticks for Industrial Research (New York: The Ronald Press Company, 1959), p. 15.

(2) total investment in the research and development program, and (3) income from royalty payments. Typical of the quantitative techniques in use are the following:

Company A

A large oil company evaluates its research contribution every five years. In making the appraisal it estimates and sums for the five-year period actual benefits from (1) the elimination of royalty payments it otherwise would have made, an estimation said to be reasonably simple; (2) improvements of existing products and processes resulting in investment savings, operating cost savings, and increased product sales; (3) additional sales from new products. The estimate of benefits is accomplished by a committee. How these benefits are compared against research costs and what standard has been set as an acceptable level of contribution were not ascertainable.

Company B

An oil company is reported to credit research with the total profit from a new or improved product in the best year following its introduction. To this are added the savings in cost for one year from process improvements, the net profit for one year on new processes, and all royalties or sales of rights obtained from patents generated by research.[47]

Even though these methods of evaluating results are termed quantitative, many of the appraisals inherent in the use of such formulas are largely subjective. Thus in a large measure, the results of the use of the quantitative approach are no better than the judgment of the individuals concerned. Because of this factor many research concerns believe that quantitative measures are misleading and they prefer to evaluate by qualitative means.

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[47] Ibid., pp. 16-18.

Qualitative Methods

Those companies which reject quantitative techniques prefer to evaluate research primarily by means of composite management judgments. In this approach each facet of the research program is appraised on a judgment basis. There is no attempt made to establish a single quantitative measure of the overall research and development contribution.

Most qualitative evaluation systems appear to follow a fairly similar pattern. In making the subjective appraisals of the various aspects of the program a series of personal opinions is pyramided through the organization from the working level to the very top management level. At each level a technical executive evaluates the results of the research groups reporting to him. Some of these appraisals are part of the executive's day-to-day job; others are formal periodic reviews intended to ensure that the program is on the right track and that results correspond to the effort being expended. Normally, a committee of operating and research executives makes such reviews with the forthcoming research budget frequently being set in coordination with the evaluation review. When lower and intermediate appraisals reach top management it is not uncommon that these nontechnical executives must rely on the top technical man to explain and interpret the technical progress that has been made. This system obviously requires a great deal of faith in the top technical executive of the organization.

The stance of these organizations which utilize the qualitative evaluation technique is probably best illustrated by comments such as these:

> We know from experience that research and development pay for themselves. We don't need any figures to tell us that.
>
> Broad composite management judgments rather than precise mathematical measures are the basis for saying whether the research program is worthwhile. Attempts at quantification of measurements do not appear to be fruitful at this time.
>
> There is no way to say how well you are doing with your research in a current year other than a composite feeling developed from a comparison of progress on projects with progress expected.[48]

The Integrated Approach

The third and least utilized approach to the evaluation problem is often termed the integrated approach. None of the companies whose systems were reviewed in available literature on the subject seemed to rely solely on the integrated approach, though some indicated that the primary criterion of evaluating research management was the degree to which research is integrated into company plans and capacities.

Basically, this theory holds that evaluation of the research effort is best accomplished by considering how well the research program is integrated into the operating structure and objectives of the concern. Both quantitative and qualitative techniques are used in making this evaluation. The integrated approach differs from the other two methods in the evaluation criteria it uses and in its emphasis upon the research program supporting company operating objectives.

This school of thought holds that industrial research is not a separate activity of an industrial concern but is an integral part of the

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[48] Ibid., p. 23.

entire organization. The research department is held responsible for providing required technology for the company just as sales is held responsible for supplying customers. The objectives of research, therefore, can be expressed only in terms of the needs of the particular company supporting the research effort. Once these objectives are defined, they also define the responsibilities of the research organization and form the basis for measuring its effectiveness.

The integrated approach to research evaluation does not appear to be a valid evaluation technique in the true sense of the word. No one can argue with the principles projected by the practitioners of this method--that research should be integrated with company operations and should support company objectives. However, these principles should be utilized "before the fact." They are the governing principles that management should follow in the initial design of the research program, not the criteria that should be used to adequately measure research and development output. Even though properly integrated, research can produce too much or too little, the right type or the wrong type, timely or untimely results. The real problem in evaluation then is the devising of adequate criteria for appraising the needed and actually acquired research results.

A Truly Comprehensive Evaluation System?

None of the approaches to evaluating research and development results which were discussed in the preceding section seems to offer one which by itself would provide management with a truly comprehensive assessment of the

research effort being made in the organization. Each of the approaches suffers in one way or another from certain limitations. What management would like to have is an evaluation system which could tell it with surety,

> . . . in 1958 research provided knowledge about new product A, product improvement B, etc. In 1959 this knowledge enables us to increase profits by $100,000, in 1960 by $200,000, etc. Since the knowledge that led to the marketing of product A and improved process B cost $200,000, the projects were worthwhile.[49]

Whether management will ever be able to evaluate the entire research program with this amount of certainty and in such detail is questionable. There is a real dearth of material in available literature regarding systems which can evaluate research output in the manner to which at least some parts of management would like to become accustomed. Perhaps the problem is too complicated ever to lend itself to adequate solution. Perhaps merely knowing that research is profitable is sufficient evaluation. Is it really necessary to prove the obvious?

In any case, in order to point out that management has not yet given up on the problem of devising a satisfactory evaluation system and to present the approach of at least one progressive thinker on this matter, the remainder of this section is devoted to a description of the most comprehensive system encountered in the research for this thesis. The description is based on the writings of James Brian Quinn.[50] Quinn's approach to the evaluation problem is based on a segmental evaluation which is then linked together to

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[49] Ibid., p. 9.

[50] James Brian Quinn, Yardsticks for Industrial Research; "How to Evaluate Research Output, "Harvard Business Review, March-April, 1960, pp. 69-80; and "Control of Research and Development Costs," The Journal of Accountancy, October, 1960, pp. 51-59.

permit an adequate assessment of the whole research program. He contends that management must stop looking for aggregate measures which do not exist and must develop performance measures that clearly measure the research program in terms of the real determinants of research success.

What Is To Be Measured?

In order properly to evaluate a research program it is first necessary to determine what results a research program might possibly produce. Research is usually thought of as directly producing certain economic benefits. This is the basis for quantitative approaches to evaluation. In reality, the economic outgrowths of research are a kind of indirect product. Research does not directly produce sales or profits or process savings. It produces only the technology upon which such economic benefits may be based. This technology is the only direct product of research and may vary from oral ideas, through drafted specifications, to concrete materials, prototypes, etc. Before any of these forms of technology reach economic fruition, they must first be exploited by the rest of the enterprise. Therefore, in economic terms research directly produces only "technical opportunities to exploit," not the results of exploitation. The economic yields of sales, profits, savings, etc. are the "indirect products of research."

With this basic premise in mind it is then possible to list at least three important determinants of the success of a research program.

1. The economic value of the technology and products produced as opposed to the cost of the research which produced it.

2. The amount of technological output per unit of scientific effort, viz., productivity.

3. The degree to which the program output supports company goals.

Economic Evaluation of Direct Products

The economic evaluation of research requires an appraisal of the opportunities to exploit and also an appraisal of the actual profits a company has realized from exploitation.

The evaluation of opportunities to exploit, the direct product of research, is probably best described in terms of an analogy, the evaluation of underground resources. The problem of placing a value on the exploitation opportunity offered by a vein of gold or a pool of oil is similar in many respects to that in evaluating research opportunities to exploit. The underground resource offers an opportunity with unknown potentialities for profit. Exploiting the opportunity would require further capital investments and could only be accomplished by the entire organization working as a team. So it is with research output.

The actual assessment of the value of an underground resource or a technological opportunity to exploit can be accomplished in a number of ways.

The unadjusted income basis computes the total expected net revenues from the opportunity. The formula for calculating values by this method is:

$$V = V_1 + \sum_{i=o}^{n} (I_i)$$

where:

V = the value of the opportunity

V_1 = the present liquidation value of the resource on a nonincome producing basis

I_i = the net profit in each i th year

n = the total number of years hence that the last income is expected.

This basis assumes that the value of an exploitation opportunity is its present resale value as nonincome property plus the sum of the best estimates of the income increments over its economic life. This method does not adjust for alternative opportunities for investing funds or for the risk factor inherent in obtaining the revenues. The advantages of the unadjusted income basis are its simplicity, its utility for use in direct comparisons with direct exploitation revenues, and its avoidance of the need of quantified risk estimates and timing of revenues.

The capitalized earnings basis computes the value of the exploitation opportunity as the sum of its present liquidation value plus a certain number of years of expected earnings. The formula would be:

$$V = V_1 + y\ (Ia)$$

where:

V = the value of the opportunity

V_1 = the present liquidation value on a nonincome producing basis

y = the number of years earnings appropriate for this class of risk

Ia = the average annual net income during period y.

The factor y is the risk factor. As the risk of investment decreases, y increases; high risk opportunities would be capitalized on a two-to five-year basis, middle risks on a five-to ten-year basis, and very low risks on a more than ten-year basis. Risk factors must be determined by experience and the going rate on similar risk classes, thus they are a subjective estimate.

The calculated risk basis adjusts the best estimates of exploitation incomes by a factor representing the probabilities of obtaining the incomes. This formula would be:

$$V = V_1 + \sum_{i=o}^{n} (P\ Ii)$$

where:

V = the value of the opportunity

V_1 = the present liquidation value on a nonincome producing basis

P = the probability of receipt of the income (Ii) in year i

Ii = the net income in each i th year

i = the number of years hence that income Ii is expected.

n = the total number of years hence that the last income is expected.

In this instance P is the risk factor and must be determined on a judgment basis.

The present value approach computes the present value of the series of cash flows which the company can expect if it properly exploits its opportunity. The present value can be computed by:

$$V = V_1 + \sum_{i=o}^{n} \overline{Ci}\ (1 + R)^{-i}$$

where:

V = the present value of the opportunity

V_1 = the present liquidation value on a nonincome producing basis

Ci = the net cash flow in each i th year

R = the expected rate of return on this class of risk

i = the number of years between the present and the i th year

n = the total number of years hence that the last income is expected

This approach discounts expected cash flows on the basis of the risk inherent in the investment opportunity class and the timing of the cash flows. The value of an exploitation opportunity under this theory is the cost of obtaining the expected incomes from alternative sources if investment in this risk class were possible at a rate of return of R. The present value method appears more complicated than it really is. The $(1 + R)^{-i}$ factor can be found in any book of financial tables. Consequently, one given R, cash flows, and timing of cash flows, V is computed as easily as by other methods. The fact that more and more companies are using this method to evaluate all general capital acquisitions indicates its efficacy.

Any of the above systems could be used to compute the worth of a research-produced exploitation opportunity. If the information required for use in these methods is properly developed and presented, management will have an opportunity to consider all important economic variables in evaluating the direct results of industrial research. It should be recognized that after the output is measured it must be compared against some standard

to check its adequacy. Not all results are usable to the organization concerned. Should results be such as to direct the company into markets it has no wish to develop or which would yield an inadequate rate of return, the direct research results are not useful to the company. Consequently, standards suitable to the particular risk class involved must be developed to enable proper decisions to be made.

Economic Evaluation of Indirect Products

Although research may result in many opportunities to exploit, it is only through actual exploitation that a company realizes a return on its research investment. Obviously, a company sponsoring research will want to measure the economic benefits it has obtained from each segment of the research program. In order to measure this economic impact, profits that would not have been possible without the research result must be determined. This is the alternative cost of not performing research. This cost is the loss of all profits yielded to date by exploiting the technology resulting from research, plus the loss of the present value of all future returns its further exploitation will yield.

Currently used procedures for quantitatively measuring profits, such as dividing the total profitability of new products by the total research costs, are subject to several weaknesses. The primary objection to these methods is that they do not adjust for the average time delay between the date research money is invested and the date profits are realized from the investment. Since research investment should be compared with alternative

uses of funds, research return calculations should make allowance for time delay factors. Sometimes companies announce that their one dollar of research spent today will yield one dollar of profits each year after a development period of five to ten years. They conclude, therefore, that research investment earns 100% per year or a 1000% total return on a ten-year product life. One dollar of research thus earns ten dollars of profits. This is not so in fact. The research investment must be idle for five or ten years before it yields any return, and additional cash investments are probably required for exploitation. These factors must be considered for a true value to be placed on the product resulting from a research investment.

Another major objection to current measures is that they do not analyze the research of the current period. They analyze only the research efforts of several years ago. Consequently their conclusions can do little more to aid management in making decisions on current appropriation requests than to say that today's research will be as profitable as that of five years ago. This assumption is suspect.

Actual profits from research are best evaluated by comparing past and future exploitation profits yielded by a particular opportunity with the best estimate of the overall research and development cost of obtaining the exploitation opportunity. Research costs of the entire research and development period should be carefully computed. Then the actual incremental profit made possible by sales of the product developed should be taken as the best measure of the alternative cost of not having performed the research. A research return ratio can then be computed as:

$$\text{Research Return Ratio} = \frac{A + P}{Ia\ (T)}$$

where:

A = the actual profits from exploitation to date

P = the present value of future profits from having the product in the company line

Ia = the average research investment in this product area from the inception of research to the last significant discounted future revenue

T = the length of time Ia is invested

This procedure has several advantages. The actual profits from exploiting technology can be computed and broughtup to date, thus even exploitations begun only recently can be considered as well as those started some time ago. Because of its currency, the research return ratio can assist in guiding current research efforts into those areas which offer the highest profit potential and helps point out to management those areas where exploitation returns have been low. Thus, patterns of commercial success or failure can be observed and future research can be better planned from this observation of past experience.

The formula adjusts for the most important factors governing return on research expenditures in that it makes allowance for the length of time the research investment will be made; it discounts future profits on a risk basis and thereby provides an automatic cut off date for return; and it considers both past and future revenues and relates them to the research costs which brought them about. However, it must be recognized that unavoidable

inaccuracies in estimates of A, P, Ia, and T do have an effect on the precision of the formula. It should be pointed out that the research return ratio is not a true return on investment calculation since the investment base does not include all plant investments required to exploit the research result. It only measures the relationship between the alternative cost of not performing the research and the research and development expenditure.

As in the case of direct research products some standard is necessary in order to determine whether the research return ratio is adequate or inadequate. In the case of new products high risks are normally involved. Many companies set a standard of 30 per cent or more on the whole investment required to obtain the return. If the research return ratio is multiplied by the percentage of the total investment represented by research costs, the adjusted research return ratio should exceed the standard percentage of return as determined by management.

$$\text{Research Return Ratio} \times \frac{\text{Research Investment in New Product}}{\text{Total investment in new product}} = \text{Adjusted research return ratio}$$

Productivity

In evaluating the research program management is also interested in the efficiency and quality of research work being conducted.

Evaluating the efficiency with which research results are accomplished is a matter of comparing a project's actual costs against some standard which states how much the project should have cost. Assuming accurate measures of both factors, research efficiency could be assessed by the ratio:

$$\text{Efficiency} = \frac{\text{Cost of best method of attacking a project}}{\text{Actual cost of the project}}$$

Actual cost is relatively easy to measure. But computing the cost of the best method of accomplishing the work is a different matter. Such an estimate is extremely difficult to make and is almost completely subjective. It should be made only by careful estimates based on a thorough understanding of the particular problem involved and upon broad experience with similar problems. There is no satisfactory method for quantitatively measuring this best method, hence the standard against which actual costs are compared is both qualitative and must be developed after the work is completed, except in those instances where the work is in the most applied phases of research.

Likewise, the quality of research results can only be judged in a subjective manner. No applicable quantitative criteria for evaluating the quality of research results were found in the literature. Such criteria, if they exist, can only be quantifications of subjective judgments. This does not mean that management cannot make these evaluations realistically--there are some criteria which some managers have found helpful in evaluating the quality of research output. Some of these are commercial successes, competitor's research results, the number of major advances, the timing of major advances, and the comparative costs of these advances.

Support of Company Goals

Management must know the answer to the question of whether the research program is producing the right kind of technology in order properly to sum up

the segments of the overall research effort.

Potentially profitable technology is not necessarily good technology for the company concerned. It is apparent that an adequate evaluation system must consider research results in the light of the particular objectives and capacities of the company. Not only must research produce technology with a dollar value sufficiently in excess of its costs to justify the expenditures, but must also produce the kind of technology the company needs to attain its goals. For instance, a chemical company has no business making research expenditures for the development of a new tractor motor.

Both planned and unplanned results must be evaluated against company objectives. This management evaluation is aided to some extent by certain indicators. If output is too low relative to company needs, the company will lose its sales position as products become outmoded. If output is too high, exploitation opportunities remain on the shelf. This latter situation would result in a low percentage relationship between the direct and indirect products of research. This relationship can be quantified as follows:

$$\text{Exploitation Ratio} = \frac{\text{Value of the Indirect Product of Research}}{\text{Value of the Direct Product of Research}}$$

Full exploitation of research results is achieved as the ratio approaches one. Low exploitation results in values less than one. Outstanding exploitation would create values greater than one. The exploitation ratio, however, only assists in the evaluation of how well the segments of the research effort are supporting company goals. Management can achieve this evaluation only by appraising the performance of research managers in the

nontechnical aspect of their jobs of keeping the research efforts pointed in the right direction.

Summary

All companies consciously or unconsciously attempt to appraise the overall contribution of the research and development effort. However, different criteria and different techniques are required to evaluate the different segments of an industrial research program. These different techniques and criteria can no more be integrated into one measure of effectiveness than apples and oranges can be summed. Appraisals of research accomplishment should carefully assess each major segment of research effort with an assessment of overall research effectiveness being made only as a composite judgment of qualified individuals.

CHAPTER V

CONCLUSIONS

There is no indication that the phenomenal growth of industrial research and development which has been so marked since World War II, is in any sense slackening. Quite the opposite is true. The trend of research expenditures during the last five years has been upwards at an ever quickening rate. It appears that research feeds on itself. New knowledge breeds new products as well as new or improved processes which in turn raise production capacities. This results in raising our standard of living to a point where increased demand for new or improved products again provides the impetus to search for yet newer knowledge, thus ever adding to our total body of technological and scientific know-how. Eventually, this rise in research spending must taper off to enable a proper balance between research and other industrial functions to be attained. The optimum combination of these interdependent activities is indeterminable at the present time. It will vary in accordance with the changes within each type of industry and in our total economy brought about by the unknown factors of the future. Although any forecast of research expenditures is subject to very wide ranges of error due to this fact, it appears plain that no slow-down in the rate of spending can be expected in the foreseeable future.

In view of this tremendous number of dollars presently being expended on research efforts and the still larger amounts expected to be spent in the next decade, it behooves management to employ the most sophisticated financial control measures possible to ensure that the research budget is being efficiently expended in those areas which offer utility to the particular organization concerned. Otherwise, a company may find itself falling far behind its competitors in the development of new or improved product lines with a resultant loss in its share of the market. In addition, the very size of required research expenditures engenders the possibility of the loss of substantial amounts of funds through ill-advised or untimely research projects unless adequate control procedures are instituted. In order for a company to maintain current competitive position or continue to grow, it is, therefore, imperative that the research program be properly organized and integrated into the company's operations in such a manner that effort and talent will be concentrated on projects that are conducive to producing results susceptible to commercial exploitation within the company's sphere of product activity. The degree of effectiveness obtained from research expenditures is directly related to the detail with which the research program is planned and controlled. Such control, however, must be exercised in a manner which will not curb to any great degree the creativity and curiosity which is a part of every good researcher.

To accomplish this, management must provide answers to the basic problems inherent in proper planning and control of research expenditures. First of all, total funds must be made available in amounts consistent with the company's research goals. These funds must not only accommodate the

financing of research and development operations, but must also anticipate the amounts of investment capital which will be required to properly exploit and market the research results produced by the program. With regard to financing research operations, management must be cognizant of the fact that the continuity and stability of the research program should be maintained by the consistent allocation of relatively stable amounts of funds from year to year.

The second important decision management must make is the selection of individual research projects. Projects selected must be in consonance with company objectives; must be within the immediate research capability of the company; and must provide an integrated and balanced program encompassing proper proportions of basic research, new product research, and present product improvement research. Once it is determined that a project conforms to company research objectives and is within research capability, other relevant business considerations must be weighed in making project decisions. Management must consider project proposals in the light of their effect on current operations, whether their results can be utilized by the company or not, and their economic aspects. In the latter regard, total costs of research, development, and production facilities must be weighed against the potential return on the research investment.

The third area for management consideration in planning the research program is devising financial control procedures which will ensure that funds are properly spent or are saved. This entails the establishment of a detailed budget which provides for the allocation of funds to specific projects and

prescribes the rate at which these funds are to be utilized. Adequate control measures also require assurance that funds are being expended as the budget dictates. This must be accomplished by instituting a cost reporting system that provides management with the means of comparing budgeted against actual costs, thus giving management the assurance it needs that the program is proceeding as planned.

The final problem which must be faced in research and development operations is the development of a system which will realistically evaluate the results of the research program and provide a measure of actual benefits realized in comparison with expenditures made. In this respect there does not seem to be any way of realistically measuring quantitatively the performance of the research organization in the aggregate, nor is it likely that such a device can be developed. Such measures in a large part are subject to errors of judgment in making estimates of projected sales, cost, etc. which form many of the formulae inputs. Further, certain aspects of research, such as quality and efficiency of work performed, do not lend themselves to quantitative analysis. More likely, research output will continue to be evaluated by a combination of quantitative factors, where appropriate, and qualitative factors where experience and judgment will best serve.

In summary, it can be said that even though there are acknowledged and important intangibles involved in the planning and control of research and development funds, proper procedures can and must be instituted to ensure that the expenditure of corporate funds for research and development results in tangible benefits for the owners. Admittedly, this can be difficult but

research expenditures can be planned, controlled, and evaluated, perhaps not perfectly but reasonably, if management is embued with the proper philosophy of research and incorporates research and development planning as part of top management's total planning activities.

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